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Factor Analysis: Some Basic Principles and an Application

By Frederick V. Waugh

Economists have paid very little attention to the statistical methods known as "factor analysis" or "component analysis." These methods were developed primarily by psychologists. Sociologists have also used them to some extent. These methods may eventually help economists to solve some of their problems. With this in mind, the author has tried to set forth the basic principles of factor analysis, and to indicate how the U.S. Department of Agriculture has used them to establish county level-of-living indexes for farm families in the United States. Those readers who are interested in a full, detailed, theoretical treatment of the subject might well read Harman's recent book which also includes an extensive bibliography.[1] Hagood and Price [2] discuss applications to sociological research. Tintner [3] discusses uses in economic research. The author thanks Ralph Champion, Farm Population Branch, ERS, for his help.

COUNTY INDEXES of levels of living are weighted averages of certain county census data, such as the percentages of farms with telephones, automobiles, home freezers, average value of farm products sold, and average value of land and buildings. Factor analysis helps determine which census elements to use and how to weight each element.

We shall show here that factor analysis maximizes the variance of the index, and that it also maximizes the sum of the squared correlations between the index and the several elements. Maximum variation in the index enables it to discriminate effectively between high, medium, and low levels.

To avoid excessive length, this problem is illustrated by considering an index based upon only three elements, say, X_1, X_2, and X_3. If I is the index, it can be written

$$I=K+b_1X_1+b_2X_2+b_3X_3, \tag{1}$$

where K, b_1, b_2, and b_3 are constants to be determined in the analysis.

If lower-case letters are used to indicate deviations from the national averages, equation (1) can be written

$$i=b_1x_1+b_2x_2+b_3x_3 \tag{2}$$

If the x's are standardized by dividing each by its standard deviation, equation (2) can be written

$$i=w_1z_1+w_2z_2+w_3z_3 \tag{3}$$

where w_1, w_2, w_3 are the weights to z_1, z_2, z_3.

The weights should be assigned in such a way as to provide a great deal of variation in the index so that it will discriminate most effectively between counties that have high, medium, and low levels of living.

The variance of the index is

$$\text{var } i=\frac{1}{n}\sum i^2=w_1^2+2r_{12}w_1w_2+2r_{13}w_1w_3+w_2^2+2r_{23}w_2w_3+w_3^2, \tag{4}$$

where r_{12}, r_{13}, and r_{23} are zero-order correlation coefficients.

As it stands, this variance has no maximum; that is, it could be increased indefinitely by multiplying all of the w's by a constant greater than 1. For instance, if each w were multiplied by 2, the variance of i would be multiplied by 4. To avoid this arbitrary result, we propose to maximize the variance of i, subject to the condition (or restraint) that the sum of the squared weights is unity; that is, so that

$$w_1^2+w_2^2+w_3^2=1 \tag{5}$$

To do this, we shall use a Lagrange multiplier. Such multipliers are discussed in modern texts on

1. Harry H. Harman, *Modern Factor Analysis*. Univ. of Chicago Press, 1960.

2. Margaret Jarman Hagood and Daniel O. Price, *Statistics for Sociologists*. Henry Holt & Co., New York, rev. ed., 1952. Ch. 26.

3. Gerhard Tintner, *Econometrics*. Wiley and Sons, New York, 1952. Ch. 6.

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advanced calculus[4] and in some books on economic theory.[5] In order to maximize (4) subject to condition (5) we can maximize

$$F = \text{var } i - g(w_1^2 + w_2^2 + w_3^2 - 1), \tag{6}$$

where g is known as a Lagrange multiplier. We can maximize F in equation (6) by differentiating it with respect to w_1, w_2, w_3, and g, and setting all the derivatives equal to zero. This gives us

$$\begin{aligned} (1-g)w_1 + r_{12}w_2 + r_{13}w_3 &= 0 \\ r_{12}w_1 + (1-g)w_2 + r_{23}w_3 &= 0 \\ r_{13}w_1 + r_{23}w_2 + (1-g)w_3 &= 0 \\ w_1{}^2 + w_2{}^2 + w_3{}^2 &= 1 \end{aligned} \tag{7}$$

While these equations are necessary for a maximum solution, they are not sufficient. In other words, equations (7) may be satisfied with some values of g that result in a minimum F and some may result in neither a minimum nor a maximum. In order to have a true maximum, it is necessary that equations (7) be met, and also that the Hessian matrix

$$H = \begin{bmatrix} 1-g & r_{12} & r_{13} \\ r_{12} & 1-g & r_{23} \\ r_{13} & r_{23} & 1-g \end{bmatrix} \tag{8}$$

be negative definite; that is, all diagonal elements of H must be negative, all principal 2-row determinants must be positive, all 3-row principal determinants must be negative, and so on. Thus, it is clear that in order to have a maximum solution, g must be greater than 1. In general, there will always be several values of g that will satisfy equations (7). In the case of three variables, there will be three such values of g. In the case of n variables, there will be n different values of g that will satisfy the equations. Any value of g that satisfies the equation is known as the root of the matrix shown in (8). We are concerned here with the maximum positive root, which is often known as the "dominant" root. In order to understand the meaning of the dominant root and also to give the basis of an iterative method of solving equations (7) the equations can be written in the form

$$\begin{aligned} w_1 + r_{12}w_2 + r_{13}w_3 &= gw_1 \\ r_{12}w_1 + w_2 + r_{23}w_3 &= gw_2 \\ r_{13}w_1 + r_{23}w_2 + w_3 &= gw_3 \end{aligned} \tag{9}$$

If the first equation is multiplied by w_1, the second by w_2, and the third by w_3, and three equations are added, the result is

$$\text{var } i = g(w_1{}^2 + w_2{}^2 + w_3{}^2) \tag{10}$$

Since the squares of the weights are subject to condition (5), equation (10) indicates that the dominant root g equals the variance of the index. Thus, as is often the case, the Lagrange multiplier g turns out to have a real statistical meaning.

The correlation between the z's and the index can be found by multiplying equation (3) successively by z_1, by z_2, and by z_3, and dividing each product by the standard deviation of the index (i.e., by $\sqrt{g}$). Then using (9), we find that

$$\begin{aligned} r_{z_1 i} &= \frac{w_1 + r_{12}w_2 + r_{13}w_3}{\sqrt{g}} = \sqrt{g} \cdot w_1 \\ r_{z_2 i} &= \frac{r_{12}w_1 + w_2 + r_{23}w_3}{\sqrt{g}} = \sqrt{g} \cdot w_2 \\ r_{z_3 i} &= \frac{r_{13}w_1 + r_{23}w_2 + w_3}{\sqrt{g}} = \sqrt{g} \cdot w_3 \end{aligned} \tag{11}$$

The sum of the squared correlations is

$$r_{z_1 i}^2 + r_{z_2 i}^2 + r_{z_3 i}^2 = g(w_1^2 + w_2^2 + w_3^2) \tag{12}$$

Since the sum of the squared weights is 1, the Lagrange multiplier also equals the sum of the squared correlations between the index and its elements. In the process of maximizing the variance of the index, we also maximize the sum of squared correlations.

Three Problems of Computation

There are three main practical problems in computing the index: (1) solving equations (7) to determine the weights associated with any particular set of census items, (2) comparing the results obtained by forming indexes from dif-

[4] Angus E. Taylor, *Advanced Calculus*. Ginn & Co., Boston. 1955. pp. 198–204.

[5] Paul A. Samuelson, *Foundations of Economic Analysis*. Harvard Univ. Press. 1958. pp. 362–365.

ferent groups of census items and determining which group to select, and (3) transforming the index into the most usable form. Each of these will be discussed briefly here. Then a numerical problem will be analyzed to illustrate the procedures.

Solving Equations (7)

Equations (7) can be solved by either of two processes: First, one could set the determinant of the coefficients of the first three equations equal to zero, solve for g, and then solve for the w's. In a problem of only three variables, this is a reasonably simple operation. However, when dealing with a large number of variables, such a direct solution is very time-consuming and laborious. In any case, it is possible to solve the equivalent equations (9) by an iterative process. One simply starts with any assumed initial values of the w's, inserts them into the left side of equation (9), and computes the second approximations of the weights. This process will be illustrated in the solution of the numerical example.

Comparing Sets of Census Items

Indexes can be computed for various sets of 3, 4, 5 or more census items. In general, we want an index that has a large variance. In comparing the results of several indexes, each of which is based on n items, we should ordinarily choose the one that gives the greatest variance. Sometimes, however, the addition of an item to an index may not increase the variance "significantly." Here there are perhaps no hard and fast rules for choosing between an index based on n variables and an index based on $n+1$ variables. Some statisticians have used as a general guide the variance divided by the number of items in the index. This is the same as the average of the squared correlations between the index and the several elements. I do not think that this sort of guide should be followed rigidly nor uncritically. If it were, one would always choose an index based upon a single element. Then the squared correlation would be 1, since the correlation of any variable with itself is 1. No index based upon more than one element could give an average squared correlation higher than 1.

The variance (or sum of squared correlations) in the 3-variable problem to be discussed next is 2.456—an average of 0.815. The final index used in this report is based upon 5 variables. Its variance (or sum of squared correlations) is 3.115—an average squared correlation of 0.623. Yet the additions of two items not only seems desirable from general considerations, but also raises the variance of the index by almost 27 percent.

Scaling the Index

The index so far described is in terms of the z's. Specifically, it can be written

$$I=w_1z_1+w_2z_2+w_3z_3 \tag{13}$$

But each $z_i=x_i/s_i$, where s_i is the standard deviation of X_i. So the index can be written

$$w_1\frac{X_1}{s_1}+w_2\frac{X_2}{s_2}+w_3\frac{X_3}{s_3} \tag{14}$$

Commonly we want to scale the index in such a way that it meets two criteria: (1) when all the items are 0, the index is to be 0; and, (2) when the value of each item in the index is at the national average, the index should be 100. We can scale the index by determining a constant k such that

$$k\left(w_1\frac{\overline{X}_1}{s_1}+w_2\frac{\overline{X}_2}{s_2}+w_3\frac{\overline{X}_3}{s_3}\right)=100, \tag{15}$$

where $\overline{X}_1$, $\overline{X}_2$, $\overline{X}_3$ are the national averages of X_1, X_2, X_3.

Then the scaled index is

$$I_s=\frac{kw_1}{s_1}X_1+\frac{kw_2}{s_2}X_2+\frac{kw_3}{s_3}X_3 \tag{16}$$

A Numerical Example

To illustrate the methods described above, let us construct a level-of-living index based upon only three Census items in each county. These three items will be the percentages of farms with telephones, with homefreezers, and with automobiles. The zero-order correlation coefficients are

$$R=\begin{bmatrix} 1.000 & 0.633 & 0.823 \\ 0.633 & 1.000 & 0.683 \\ 0.823 & 0.683 & 1.000 \end{bmatrix} \tag{17}$$

where the order of the three variables is as indicated just above (17).

To get weights for the index we must solve a set of equations such as (7) or the equivalent (9). Equations corresponding to (9) are

$$
(18) \qquad \begin{aligned} w_1+0.633w_2+0.823w_3&=gw_1 \\ 0.633w_1+w_2+0.683w_3&=gw_2 \\ 0.823w_1+0.683w_2+w_3&=gw_3 \end{aligned}
$$

This set of equations has the obvious trivial solution $w_1=w_2=w_3=0$. It also has three nontrivial solutions, each with a different value of g. We are interested here in a solution with the largest positive value of g.

One way of finding such a solution is an iterative process, starting with an arbitrary set of trial values, such as $w_1=w_2=w_3=1.0$. (Here we are concerned only with the proportions between the weights. We do not yet require that the sum of the squared weights equal 1.) Substituting $w_1=w_2=w_3=1.0$ into (18), we get as a second approximation, $gw_1=2.456$, $gw_2=2.316$, $gw_3=2.506$, These numbers are shown in the first column of the lower part of (19). We could use these numbers as second approximations of our weights, but to keep the numbers comparable we shall divide each of them by the first number (i.e., by 2.456). This gives us as a second approximation the weights 1.000, 0.923, 1.020. This process can be continued indefinitely, and will eventually converge to the correct set of weights. When that happens it will be apparent that further iterations will not significantly change the weights.

A simple worksheet for this process is as follows:

Trial values of the w's

(1)	(2)	(3)	(4)	(5)	(6)
1.000	1.000	1.000	1.000	1.000	1.000
1.000	0.943	0.933	0.931	0.930	0.930
1.000	1.020	1.021	1.021	1.021	1.021

(19) Estimates of gw from (18)

2.456	2.436	2.431	2.430	2.429
2.316	2.273	2.263	2.261	2.260
2.506	2.487	2.481	2.480	2.479

After four iterations we get the set of weights 1.000, 0.930, 1.021. These are apparently correct to three decimals. These numbers are shown in the last column at the top of (19).

The sum of the squares of these numbers is 2.9073, and the square root of this sum is 1.7051. If we want the sum of squares of the index weights to equal 1.0, we must divide each of these numbers by 1.7051. This gives us the weights $w_1=0.586$, $w_2=0.545$, $w_3=0.599$. Thus, one form of the index would be $I=0.586z_1+0.545z_2+0.599z_3$. The variance of this index, in other words the value of g, is 2.429. Also, the sum of the squared correlations between the index and the three items is 2.429. This number is found at the top of the last column in the lower part of (19). It is easy to see that this number equals gw_1, for in this case w_1 is taken as 1.000. Thus the first equation in (18) shows that $2.429=g(1.000)$.

The correlations between each of the three items and the index can be found by multiplying the above weights by $\sqrt{g}$ (i.e. by 1.5586). This gives us the correlations

$$
r_{z_1 t}=0.913,\ r_{z_2 t}=0.849,\ r_{z_3 t}=0.934
$$

The standard deviations of X_1, X_2, X_3 were $s_1=23.92$, $s_2=14.66$, $s_3=15.18$. Remembering that each $z_i=x_i/s_i$, the equation $I=0.586z_1+0.545z_2+0.599z_3$ can be written.

$$
I=0.586\,\frac{x_1}{23.92}+0.545\,\frac{x_2}{14.66}+0.599\,\frac{x_3}{15.18}
$$

$$
I=0.0245x_1+0.0372x_2+0.0395x_3 \qquad (20)
$$

This index would be zero for any county with no telephones, no freezers, and no automobiles. But we would like to scale the index so that a county with the average percentages of telephones, freezers, and automobiles would have an index of 100. The national averages (unweighted means of county means) were $\bar{X}_1=64.26$, $\bar{X}_2=55.57$, $\bar{X}_3=79.19$.

Inserting these averages into the above equation (20), we would have an index of 6.7696. Multiplying all the weights in the above equation by $100/6.7696=14.77$, we get the scaled index

$$
I_s=0.362X_1+0.549X_2+0.583X_3 \qquad (21)
$$

Using this scaled index, a county with no telephones, no freezers, and no automobiles would get an index of zero. Also a county in which 64.26 percent of the farms had telephones, 55.57 percent had freezers, and 79.19 percent had automobiles would score

$$
I_s=0.362\,(64.26)+0.549\,(55.57)+0.583\,(79.19)=100
$$

Factors Affecting the Demand for Cigarettes

By S. M. Sackrin

Few commodities exhibit as strong a trend factor as do cigarettes. The phenomenal rise in popularity in this form of smoking since the early 1920's is well known, but to the analyst seeking to identify factors affecting demand for cigarettes, the strong trend factor which tends to overshadow the effects of other determining influences frequently is a vexing and frustrating obstacle. This article reports the results of statistical analyses of factors affecting the demand for cigarettes. Particular attention is given to alternative methods of handling time as a variable, and to the assumptions regarding the shape of the time trend implicit in each. **The author acknowledges the helpful suggestions of Arthur G. Conover and Anthony S. Rojko of the Economic Research Service.**

AS ANYONE can plainly observe, cigarette smoking is the dominant form of tobacco consumption in the United States, but this was not always the case. In 1920, for example, consumption of cigarettes was exceeded by that of cigars and far exceeded by the combined total of smoking tobacco, chewing tobacco, and snuff. In the 40 years or so since then, however, the growth in consumption of cigarettes, with but two notable exceptions, was uninterrupted. From a total of about 45 billion (611 per person, 15 years and over) in 1920, consumption of U.S. smokers grew to 503 billion (3,989 per person) in 1961. The tobacco consumed in cigarettes in 1961 accounted for 83 percent of all tobacco consumed in the United States.

The extraordinary growth in consumption of cigarettes has posed a problem in analyzing the factors affecting demand. At best, the disentangling of the separate effects of a number of explanatory variables is always fraught with some peril. The task of correctly assessing the influence of each is rendered more difficult by the existence of a strong time trend which may tend to overshadow the effects of other determining factors or which may have a common influence on both the dependent and independent variables. There are several ways for handling trend in statistical formulations. For example, the transformation to first differences allows for the presence of a strong time trend. But the use of a certain formulation implies a specific shape of the time trend. The question then becomes: Is the shape of the time trend implied by the formulation selected a correct representation of trend? In the course of this article, alternative statistical formulations used in the measurement of trend will be discussed, and results from analyses of factors affecting cigarette consumption used to illustrate principles involved.

Variables Considered

In most demand studies, price and disposable income are almost invariably included as factors influencing consumption of a commodity. In addition to price and income, however, there are other factors that affect consumption of cigarettes. The 1955 smoking-income survey (*6*)* showed that there are marked differences between the sexes insofar as cigarette consumption is concerned; daily consumption of women smokers on the average is around one-third less than that of male smokers. Both among men and women smokers, age differences affect consumption; heaviest consumption occurs among those 25–54 years of age. Cigarette consumption of those living off farms (urban and rural nonfarm) tends to average from 8 to 10 percent higher than that of smokers on farms. Regional differences in rates of smoking were also noted, but these basically reflect the urban-rural composition of the population in each region.

Normally, cigarette smokers are characterized by a high degree of product loyalty. Virtually all women smokers are, of course, smokers of cigarettes. But even in the case of male cigarette smokers, over 60 percent smoke cigarettes exclu-

*Italic numbers in parentheses refer to Literature Cited, page 88.

sively, according to the 1955 survey, and an additional 30 percent smoke cigarettes regularly, with an occasional cigar or pipe.

With smoking preference indicated so clearly, product substitution among cigarette smokers, barring extreme price changes, is not very likely. About the only time when there appeared to be a large-scale and fairly sustained shift from cigarettes was during the depression 1930's, particularly 1931 and 1932, when consumption of ready-made cigarettes declined, whereas that of smoking tobacco for pipes and roll-your-own cigarettes increased. But this was an extraordinary period of widespread unemployment and reduced consumer income.

Although in subsequent periods of economic recession there has been a tendency for smoking tobacco consumption to increase, these gains have usually been temporary and do not appear to have affected cigarette consumption appreciably. Because of the limited substitution for cigarettes, there does not appear to be need for introducing the price of competitive items as additional explanatory variables. As a matter of fact, when the retail price of smoking tobacco was explicitly introduced as a variable in preliminary statistical analyses, its regression coefficient was in all cases statistically nonsignificant.

Since World War II, two major developments have affected cigarette consumption. First of these has been the publicity concerning the effects of cigarette smoking on health. The successive declines in consumption in 1953 and 1954 were at least partly due to the publicity linking cigarette smoking with lung cancer. The steady growth in cigarette consumption which had been underway since the setback of the depression 1930's was interrupted, and it was 3 years before aggregate domestic consumption returned to approximately the same level as before the "health scare."

The other important development since World War II has been growth in production of filter-tip cigarettes. In 1952, at the start of the publicity concerning cigarette smoking and health, filter-tip cigarettes comprised only 1 percent of total output. In the following 7 years, this proportion grew steadily and by 1959, nearly half of all cigarettes produced were filter-tipped. Last year, the proportion increased to over half. The popularity of filter-tips undoubtedly contributed to the resumption in the upward trend in cigarette consumption. Apparently, many smokers regard them as an answer to the "health problem" and filter-tip cigarettes have a special appeal to women and younger smokers. Of some importance also is the fact that there appears to have been a tendency for those who switched to filter-tip cigarettes to consume more than they did when they smoked nonfilter cigarettes.

In summary, the factors considered for analyzing cigarette consumption were price, disposable income, the sex ratio of the population (15 years and over), the age composition of the population (15 years and over), the farm-nonfarm composition of the population (15 years and over), and, in the postwar period particularly, the effects of the "health scare" and the enormous growth in popularity of filter-tip cigarettes.

All of these factors, however, were not included in the statistical analysis. The ratio of females to males, 15 years and over, has increased almost steadily from 97 per 100 males in 1926 to about 105 per 100 males in 1958. But what is of greater importance than the overall sex ratio is the ratio of women smokers to men cigarette smokers. These data are not available except for scattered individual years. Such evidence as is available does indicate that the proportion of women smoking cigarettes has increased markedly since the 1920's. This has contributed to rising cigarette consumption, but the addition to consumption has not been as great as it would have been if the average smoking rate among women equaled that of men.

There has been remarkable stability in the proportion of males and females aged 25–54. Considering the numbers of persons in those age brackets as a percentage of all persons 15 years and over, the percentage varies only between 56 and 57 throughout the entire period 1926–58. On the other hand, in the same period there was an increase in the proportion of nonfarm persons among those of smoking age, rising from about 74 percent in 1926 to about 88 percent in 1958. This change, however, was gradual. Year-to-year changes were so slight as to make it unfeasible to introduce this variable explicitly in any first-difference analysis. And in a preliminary analysis based on actual data, the regression coefficient was not statistically significant although its sign was in accordance with expectations.

The effect of the "health scare" on cigarette consumption was most apparent in 1953 and 1954, but judging from the resumed uptrend in consumption, has been of considerably less importance since that time. Thus the two "abnormal" years can be omitted from the period used for statistical analysis.

Of the factors enumerated above, those that remained for inclusion in statistical analysis were price, income, and filter-tip cigarettes as a proportion of total cigarette consumption. The proportion of filter-tip cigarettes was not introduced explicitly as a variable, but its effect was represented by a shift variable which took on a zero value for pre-World War II years and a value of one for postwar years. To these was added a time trend, to allow for those factors which could not be introduced explicitly into the equation. These would be changes occurring gradually and affecting cigarette consumption, such as changes in taste and fashions in smoking; the growing percentage of smokers among women, and to a lesser extent, among teenagers; and the growing urbanization of the population.

As already indicated, the price of smoking tobacco was dropped as a variable, on the basis of results from preliminary analyses. Normally, the price of smoking tobacco has little effect on cigarette consumption. Unlike more usual cases of competing products, consumers do not keep the respective price of cigarettes and smoking tobacco under surveillance to decide which is the better "buy." Thus, normally, changes in prices of smoking tobacco do not by themselves win additional smokers or deter confirmed smokers.

Statistical Analysis

A series of least-squares regression analyses was made, utilizing the following variables:

- Q_t—annual per capita taxable consumption of cigarettes, population 15 years and over, in continental U.S. (packs of 20 cigarettes)
- P_r—average U.S. retail price, deflated by BLS Consumer Price Index (cents per pack)
- Y—per capita disposable income, deflated by Consumer Price Index (thousand dollars)
- T—time (1926=1)
- D—shift variable, taking on a zero value for prewar years and a value of one for postwar years
- Q_{t-1}—per capita taxable consumption of cigarettes, population 15 years and over, in continental U.S., lagged one year (packs of 20 cigarettes)

The period examined was 1926–58, omitting the war years 1942–45 and also 1953 and 1954. Both price and per capita income were deflated to put them in "real" terms, although there may be some conceptual differences of opinion concerning the advisability of deflating price.[1]

Per capita consumption in continental United States omits consumption by Armed Forces overseas. The former variable was used instead of per capita consumption of all United States smokers, including Armed Forces overseas, as interest partly centers on consumption as affected by price. The price to members of the Armed Forces overseas is considerably cheaper than the mainland price as the Federal excise and State taxes are not included. Hence the consumption variable used reflects changes in the retail price most typically confronting consumers at time of purchase.

As the BLS series on retail prices during the period under review was not considered to be completely representative because it priced only standard brands and did not fully reflect taxes in all States, a retail price series was constructed from data on manufacturers' list prices of the different kinds of cigarettes, State tax revenue, and available data on distribution markups.

In statistical analysis of demand, frequently the data are expressed in first differences to overcome the influence of trend, to reduce intercorrelation between explanatory variables, and to reduce serial correlation of residuals. In an analysis run in first differences of logarithms, per capita consumption of cigarettes was related to real price and real disposable income per capita. The following regression equation and statistical coefficients

[1] Tennant (*10*, p. 124 f.) preferred to use undeflated prices, arguing that deflation would introduce correlation between consumption and prices, even if none existed. According to this view "a deflated price is a function of the general price level, which in turn is a function of the national income." As tobacco consumption is correlated with income, it follows, according to Tennant, that it is also some function of deflated price.

were obtained. Numbers in parentheses beneath the regression coefficients are their respective standard errors.

$$\Delta \log Q_t = \underset{}{0.0146} - \underset{(0.10)}{0.56}\ \Delta \log P_r + \underset{(0.07)}{0.45}\ \Delta \log Y \qquad R^2 = 0.84 \quad (1)$$

The constant term is a measure of residual trend, as it implies that even if there were no change in the explanatory variables, per capita consumption of cigarettes would increase by 3.4 percent a year. (The antilog of 0.0146 is 1.034.) When calculated values were computed, however, residuals for most prewar years were positive, whereas those for most postwar years were negative. The reason was attributed to a faulty representation of trend. This prompted a closer examination of the shape of the time trend implicit in a first differences of logarithms analysis.

Differences in Shape of Time Trend

Many analysts may not be aware of the fact that there is a fundamental difference between the shape of the time trend depending on whether (1) the logarithm of time ($\log t$) is used as an explicit variable, or (2) first differences of logarithms are used, and the constant term or "a" value (if statistically different from zero) taken as a measure of trend.[2] This is in contrast to the situation where the data are expressed in original form. In the latter case, it makes no difference in the shape of the time trend if original variables or first differences are used; the coeffcient on t or the constant term in a first difference analysis both yield a linear trend.

When first differences of logarithms are used, the constant term or the residual trend coefficient obtained from such analysis is of the exponential type, that is to say, of the form c^t. On the other hand, use of log of time as a variable is equivalent to a power function. As pointed out by Foote (*3*, p. 40) the logarithmic expression of the exponential function would be $(\log c)\ t$. By this function, as t increases, we raise c (a constant) to a progressively larger power. The resulting curve is one that is concave upward, that is, the increase expressed in actual units grows progressively larger with time. (See fig. 1.) This arises because in effect we apply a constant percentage increase to a progressively larger number, which results in progressively larger increments or an acceleration in the growth curve. Such a representation of trend is clearly inappropriate for those cases—probably the majority—where growth is rapid at first but tends to flatten out with the passing of time.

Such a trend can be obtained by introducing time explicity as a variable, and expressed in logarithmic form. This would be a curve of the type t^c or $c \log t$. A preliminary analysis of cigarette consumption which used the log of time as a variable yielded as one of the parameters $0.2627 \log t$. When the coefficient is positive but less than unity, as in this case, we get a growth curve that rises steeply at first but then flattens out. (See fig. 1.)

In order to avoid an exponential time trend, the first analysis was rerun, introducing the logarithm of time as an explicit variable. But, since the "a" value or constant term in a first differences analysis also reflects trend, it must be eliminated to avoid duplication. To center the effect of trend on the coefficient representing time, *unadjusted moments* were used.[3] The following equation and statistical coefficients were obtained:

$$\Delta \log Q_t = -\underset{(0.13)}{0.43}\ \Delta \log P_r + \underset{(0.08)}{0.53}\ \Delta \log Y + \underset{(0.03)}{0.15}\ \Delta \log T \qquad R^2 = 0.82 \quad (2)$$

Residuals computed from this analysis were more randomly distributed than when the trend representation was the exponential curve. The Durbin-Watson test for serial correlation in the residuals was inconclusive.

Additional Statistical Analyses

To take account of the effect of filter-tip cigarettes on consumption, an analysis was run relating per capita cigarette consumption to real price, real disposable income per capita, time, and

[2] The problems relating to the use of time as a variable, and alternative power and exponential functions, are discussed by Foote (*3*, pp. 39–43).

[3] The use of unadjusted moments when working with first differences is mentioned by Foote (*2*, p. 3). In the present case, the use of unadjusted moments to eliminate the "a" value or constant term in effect assumes it to be zero.

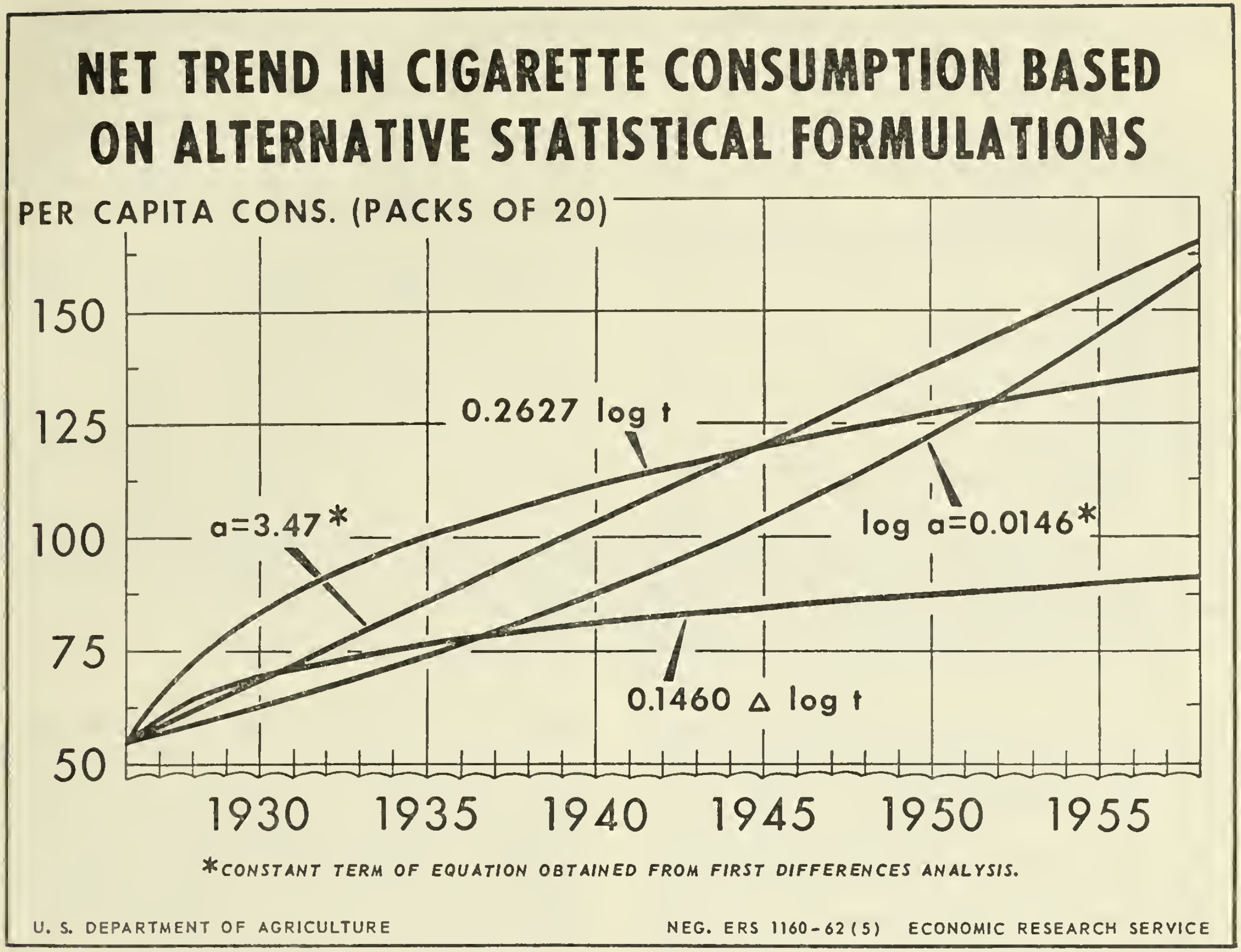

Figure 1.—The shape of the time trend depends upon the statistical formulation used. Trend curves shown here include linear trend, two power functions, and an exponential function. Regression coefficients on other variables are affected by the type of curve selected to represent trend.

a shift variable (D), which took on a value of zero for prewar years and 1 for postwar years. Original data in logarithms rather than first differences were used, because of inclusion of the shift variable. As all data were expressed in logarithms, the time trend implied by this formulation was the power function, deemed appropriate in the case of cigarette consumption. The following regression equation and statistical coefficients were obtained:

$$\text{Log } Q_t = 2.2160 - \underset{(0.15)}{0.37} \log P_r + \underset{(0.07)}{0.64} \log Y + \underset{(0.02)}{0.21} \log T + \underset{(0.02)}{0.09} \log D \qquad R^2 = 0.993 \qquad (3)$$

Another statistical analysis was made, utilizing the same variables as the foregoing but adding consumption lagged one year (Q_{t-1}) as an additional variable, since consumption in any given year is partly determined by consumption in the preceding year. This appears to be particularly applicable to cigarettes, a commodity characterized by habitual use. The following regression equation and statistical coefficients were obtained:

$$\text{Log } Q_t = 1.5283 - \underset{(0.14)}{0.29} \log P_r + \underset{(0.09)}{0.48} \log Y + \underset{(0.03)}{0.14} \log T + \underset{(0.03)}{0.04} \log D + \underset{(0.13)}{0.35} \log Q_{t-1} \qquad R^2 = 0.995 \qquad (4)$$

Note: The regression coefficient on the shift variable D is not statistically significant at the 5 percent level of probability. The Durbin-Watson test for serial correlation in the residuals was inconclusive.

TABLE 1.—*Selected parameters from statistical analyses of factors that affect consumption of cigarettes* [1]

Item	Analysis 1	Analysis 2	Analysis 3 [2]	Analysis 4 [2]
Coefficient of multiple correlation	0.84	0.82	0.993	0.995
Standard error of estimate	.009	.002	.017	.015
Constant term or intercept value	0.015	(3)	2.22	1.53
Effect on per capita consumption of a one percent change in:				
Retail price:				
Net effect	−0.56	−0.43	−0.37	−0.29
Standard error	.10	.13	.15	.14
Coefficient of partial determination	.57	.34	.20	.17
Per capita disposable income:				
Net effect	.45	.53	0.64	.48
Standard error	.07	.08	.07	.09
Coefficient of partial determination	.67	.65	.78	.59
Effect of trend:				
Regression coefficient	(4)	.15	.21	.14
Standard error	(4)	.03	.02	.03
Coefficient of partial determination	(4)	.54	.84	.46

[1] Based on data for 1926–58 (excluding 1942–45, 1953, and 1954). Analyses 1 and 2 are based on first differences of logarithms; Analyses 3 and 4, on logarithms. See text for fuller description of variables and methodology used.
[2] Analysis 3 also included a shift variable, and Analysis 4, a shift variable and lagged consumption. The coefficient obtained on consumption lagged one year was 0.35 and its standard error, 0.13.
[3] Unadjusted moments were used to eliminate the constant term.
[4] The constant term or y-intercept was equivalent to a trend increment of 3.4 percent a year.

The inclusion of lagged consumption as a variable resulted in lower regression coefficients on the other variables than when it was omitted.

Estimated Price and Income Elasticities

Price, income, and trend parameters from the alternative analyses are summarized in table 1, together with partial coefficients of determination. Results from Analyses 2–4 probably are more acceptable as they represent the effect of trend by a power function. Results from these analyses suggest that the price elasticity of demand for cigarettes is between −0.3 and −0.4, and the income elasticity of demand, about 0.5. Changes in real disposable income appear to be more influential than changes in real price in affecting cigarette consumption. The relative importance of trend is not as clear-cut. However, the reduction in the coefficient of partial determination of 0.84 in Analysis 3 to 0.46 in Analysis 4 is undoubtedly due to the inclusion of Q_{t-1} as a variable in the latter; the effect of trend is thus divided between the explicit time variable and lagged consumption.

Additional evidence of the greater influence of income than price on cigarette consumption was obtained from another analysis. In order to overcome the common influence of time, consumption and the undeflated price and income variables were expressed as ratios to their respective trends.[4] The two variables explained 78 percent of the variation in per capita consumption from its trend level. The magnitude of the partial coefficients of determination tend to support the finding that changes in income are more important than changes in price in explaining variation in per capita consumption of cigarettes.

Results of Other Investigations

Statistical studies of the factors affecting demand for cigarettes have been relatively few. In one of the earliest, Schoenberg (7) related per capita cigarette consumption to real price and trend in the period 1913 to 1931. It was found that for each increase of $1 per 1,000 cigarettes at wholesale, annual per capita consumption de-

[4] See Schultz (8, p. 68) for a discussion of the rationale of this method. The following regression equation and statistical coefficients were obtained:

$$X_1' = 1.23 - \underset{(0.23)}{0.66}\, X_2' + \underset{(0.06)}{0.41}\, X_3' \qquad R^2_{1.23} = 0.78$$
$$s_{1.23} = 0.068$$
$$r^2_{12.3} = 0.25$$
$$r^2_{13.2} = 0.64$$

where X_1' is per capita consumption of cigarettes, X_2' is average retail price, and X_3' is per capita disposable income, all expressed as ratios to their respective trend values.

clined by about 22½ cigarettes and that there was an increase of about 52 cigarettes a year due to trend. An unsuccessful attempt was made to measure the relationship with income by introducing first an index of real wages for urban workers and then an index of factory payrolls. It was found that "the influence of 'time' was still paramount, and that 'time,' not earnings, accounted almost wholly for the high correlation."

A second analysis made by Schoenberg for the years 1923–31 added newspaper advertising expenditures by the four leading cigarette companies to those used in the foregoing analysis. This analysis yielded a price elasticity of −0.68 at the means. The author also estimated elasticities for selected prices and selected years. These ranged from −0.5 to −1.3, and indicated, according to the author, that the elasticity of demand for cigarettes had been decreasing with time and that it is higher for high prices than for low prices. However, as a linear demand curve was fitted to the data, it follows that the elasticity varies at different points and that it is higher at high than low prices. This is also pointed out by Tennant (*10*, pp. 148–151), who questions other aspects of Schoenberg's analysis. Gottsegen (*4*, pp. 166–171) also critically discusses the analysis.

A study by the U.S. Treasury Department (*11*), relating consumption to retail price, income, and trend in the years 1929–43, indicated a price elasticity of approximately −0.1. The income elasticity was indicated to be larger than the price elasticity, although neither any specific figure nor any details of the analysis itself were given. The greater influence of income, as found in the study, is also indicated by the following statement (p. 15): "Because of the apparent dominant effect of the income factor, it is difficult to measure the effect attributable to price changes. However, it seems reasonably certain that price changes have had much smaller effects on total consumption than equal percentage changes in income."

Tennant (*10*) presents estimates of the elasticity of demand for all tobacco products. But in his separate discussion of the demand for cigarettes, he does not include results of statistical analysis nor a quantitative estimate of the elasticity of demand for cigarettes. However, he states, "In normal years, cigarette demand is wholly inelastic within the range of observed price variations" (p. 173).

In an analysis of the factors affecting cigarette consumption by the Federal Reserve Bank of Richmond (*1*), per capita consumption was related to real price, real disposable income per capita and trend for the years 1929–48. The price elasticity of demand at the means was estimated at −0.66 and the income elasticity at 0.59. The most influential factors affecting consumption were found to be trend and income. Although it was stated that trend appeared to be a more important factor than income, the high intercorrelation between the two variables made it difficult to be definite on this point. The effect of price was found to be of "relatively minor importance" in explaining changes in cigarette consumption.

Another approach in measuring factors influencing consumption of cigarettes was taken by Maier (*5*). Geographic cross-section analysis was employed for each of the years 1947–51, in which purchases of cigarettes per person 15 years and over in States with State cigarette taxes were related to the following: Per capita disposable income, retail price, rural-urban composition and sex composition of the population. No statistically significant relationships with the last two variables were found, but even when these were dropped from the analysis low coefficients of determination were obtained with the remaining two determining variables—price and income—for each of the 5 years examined. The regression coefficients on income implied an income elasticity at the means of around 0.5 for most of the years. Regression coefficients on price were statistically significant for only 3 of the 5 years and implied a price elasticity in the State-wide markets at the mean prices in those years of from −1.08 to −1.48. The author advances several reasons for these large magnitudes.

In an analysis of cigarette consumption in the United Kingdom for the period 1920–38, Stone (*9*) estimated the elasticity with respect to the current year's price to be −0.39 and the elasticity with respect to income to be 0.22. In Stone's overall study of consumers' expenditures and behavior in the United Kingdom, budget studies were used to estimate income elasticities for most commodities. These income elasticities were then used to adjust the data in order to estimate price elasticities. In this manner, Stone sought to overcome the problem of intercorrelation between income and the other determining variables. This

procedure, however, was not followed in the analyses of cigarette consumption, because the usual understatement of tobacco expenditures in budget data made it unfeasible to introduce such "extraneous estimator" of the income elasticity. The analysis is thus based on time-series for all variables, but with use made of aggregate consumption and income in view of the "uncertainties" as to the size of the consuming public.

The estimate of the price elasticity of demand for cigarettes derived from analyses described earlier in this article generally is lower than that estimated in other U.S. investigations also based on time series; the income elasticity is generally in accord with those derived from previous studies. Although there are some differences in the elasticity measures, stemming in part from the type of curve fitted to the data, virtually all investigations are in agreement that the demand for cigarettes is inelastic, both with respect to price and income.

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Cost, Size, and Income Relations on Cotton Farms

By Douglas D. Caton and Charles V. Moore

As farms become larger and more specialized, questions of the relationships between costs and income as affected by size become more important. This report on cost-size relations on irrigated cotton farms in the San Joaquin Valley, Calif., shows that the smaller farms, within the range of size illustrated, can pay current charges for irrigation water and remain "in the black." However, their profits disappear more readily than those on larger farms as costs of irrigation water increase. On the farms illustrated, most of the economies of scale and size are achieved by the 320-acre farm. Costs per dollar of output increase rapidly for successively smaller farms, but decrease slowly for successively larger ones.

THE EFFECT on farm costs of two main cost variables in California—size of farm and water cost—is examined in this paper. The applicability of assumptions made and of conclusions drawn is limited to the farm situations studied and the cropping systems used. Proposed water prices under the California Water Plan are emphasized in this examination of costs on cotton farms. Under the proposed water plan, the estimated price of water to farmers would be higher than the present average cost of surface or well water in the San Joaquin Valley. Costs of production would reflect the higher price.

Unit costs of production and levels of total cost are affected by other considerations, such as acreage limitations. If acreage limitations like those now being discussed are made part of the plan, farmers may not be able to take full advantage of the economies of scale that may exist. Under consideration also is a surcharge on amounts of water made available above a given water quota. The quota would be based on the water needed to irrigate 160 acres of cropland. A surcharge would further increase production costs on larger farms. Net farm income is highly correlated with farm size and cost of water, the two main cost variables considered.

Farm size has increased steadily in California in recent years. Farm numbers decreased from 144,000 in 1950 to 123,000 in 1959. About 95 percent of this decrease was the result of a consolidation of farms of 80 acres or less, principally those of less than 30 acres.[1] Increases in farm size are caused by (1) technological changes, which make larger scale farming profitable; (2) increases in cost and declines in price; and (3) basic changes in the structure of factor and product markets.

Increased use of purchased inputs and increases in the cost of these purchases have caused costs of production to increase steadily. New technology has allowed a certain amount of substitution among inputs, primarily capital for labor. Concurrently, investment requirements increased fixed costs. Many farms have high per-unit fixed costs because they have surplus or unused capacity of many production factors. Fixed costs and certain elements of variable costs can be decreased per unit of product only by spreading them over a greater amount of production. Correspondingly, price decreases for farm products have decreased net farm receipts. Maintenance of income or an increase in total farm income under these circumstances requires an expansion in the number of units produced for sale.

The second aspect of this article—water prices—was selected because of the pronounced effect of the price of water on the level of cost and thereby on total net income. Ground water from wells has both fixed and variable costs. The fixed costs of water from wells are depreciation, interest, and taxes. The variable costs consist of the repairs and power charges. Surface water costs also have both fixed and variable features. Although these cost distinctions are important in isolating marginal cost, the really important consideration is that supplemental irrigation is a requirement for summer crop production in the San Joaquin Valley.

The effect of an increase in the price of water on net farm income is related to the amount of the increase, and to the relationship between unit costs and farm size. A marked change upward in the

[1] McCorkle, C. O., Jr., Farm Production and Management—Some Present Problems and Outlook, material presented to the Assembly Committee on Agriculture, California Legislature, May 2, 1960, Davis, Calif.

price of water, which is a substantial component of total cost, will substantially reduce the net return of the smaller, higher cost farms.

Historical and Institutional Background

The farms selected to show the relation of size to unit costs and the effect on income of water costs are in the eastern and central areas of the San Joaquin Valley. The San Joaquin Valley has two distinct agricultural production areas. These two areas, called the Eastside and the Westside, differ in the nature of land and irrigation development and in crop production. High-value intensive crops on the Eastside contrast with the lower valued, more extensive agriculture of the Westside. The two areas have also marked differences in soil and other aspects of physical environment. Cotton production, however, is an exception to the distinction between the areas. Cotton, a high-value intensively cultivated crop, requires large amounts of capital. This crop was responsible for development of irrigated agricultural production in the Westside. Because of the great depth of the basic water table on the western side of the San Joaquin Valley, the high cost of pumping water can be supported only by a high-value crop such as cotton.

Farming developed first along the eastern side of the San Joaquin Valley. Then as now small farms predominated, a characteristic due to limited supplies of water that could be obtained from resident streams. Settlers were unable to finance larger farms. Much of the land on the Eastside was sold to settlers by land-development companies. These companies acquired large sections of land which were subdivided into small parcels for sale. About 78 percent of the Eastside farms are less than 100 acres in size, 67 percent having less than 60 acres each. Large farms predominate on the western side of the valley.

As land development continued along the eastern side of the San Joaquin Valley, irrigation water became necessary for intensive crop production. Water was obtained from surface irrigation projects and from wells. Resident streams proved undependable as a source of water for irrigation. Various aids and developmental programs were instituted to meet increasing demands for water. With the passage of the Reclamation Act of 1902, the Federal Government actively entered the irrigation water-development scene. Concomitant with reclamation development were laws to regulate the allocation of the limited supplies of surface water among all users. The amount of water that could be delivered to each farm owner was limited before deep-well pumping was developed.

Development of the turbine pump and other technological advances enabled Eastside farms to increase in size. But only gradual consolidation of farmland was permitted because of the historical pattern of land development, such as intensive cropping and institutional restrictions, that is, acreage limitations on cotton. Following deep-well development, the western side of the valley, always characterized by large farms that serve as the basis for its extensive pattern of farming, changed rapidly from an extensive grain and pasture agriculture to cotton and other more intensive crops.

Theoretical and Applied Analytical Procedure

A distinction is drawn between returns to scale and economies of scale in this article. Returns to scale are defined as the returns obtained when the proportion of inputs is held constant as output is increased. On a production-possibility surface, this relationship can be depicted as a straight line passing through the origin and intersecting the isoproduct curves (fig. 1).

Economies of scale can occur in two ways, owing either to technical or monetary causes. In the latter respect, economies result from a reduction in prices paid for factors of production, or because of increased prices received for products. Technological economies result from better methods of production. Operators of large farms are generally able to utilize larger, more specialized machines and to utilize labor and farm equipment more fully, opportunities that are not available to operators of smaller farms. Unless small farm operators can rent equipment and find other employment for their surplus labor, all costs must be applied against fewer product units, consequently their unit cost of output is greater. Constant returns to scale are indicated when the distance between isoproduct curves is equal. If the distance between the curves decreases, moving out from the origin, increasing returns to scale are indicated. Correspondingly, if the distance be-

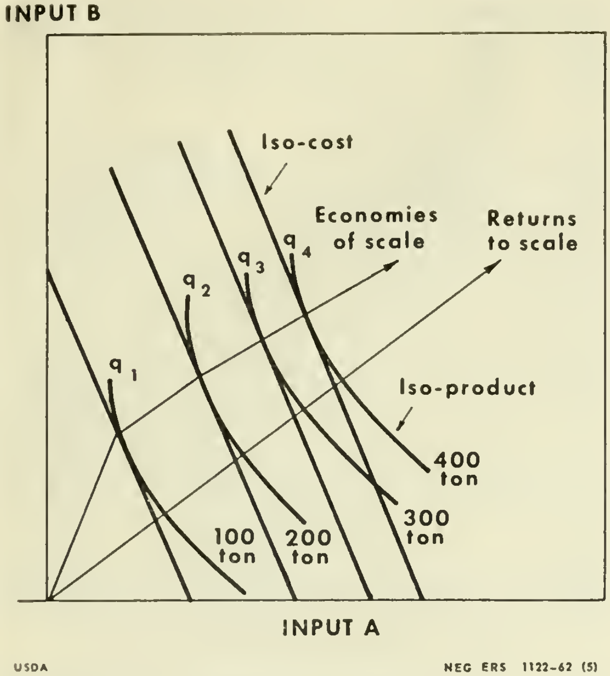

Figure 1.—Long-run production possibility surface showing alternative expansion paths.

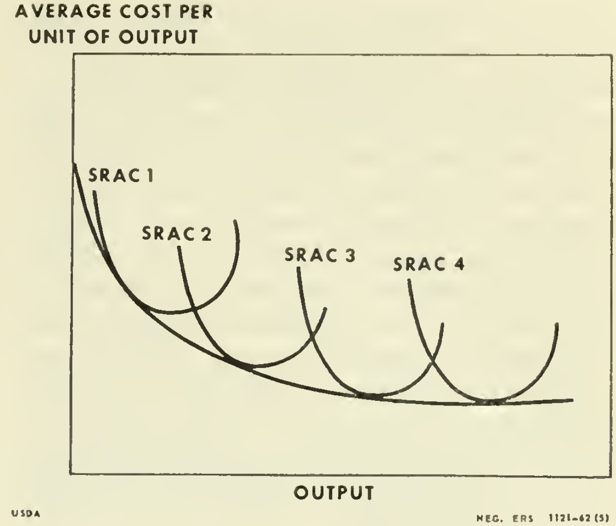

Figure 2.—Hypothetical long-run and short-run average unit cost curves for different farm sizes.

tween isoproduct curves increases as output is increased, decreasing returns to scale of production exist.

The economies-of-scale curve is defined as the locus of minimum-cost points for successive levels of output. The expansion path connects the least-cost points on the isoproduct curves for each level of output. At the point of intersection of the isoproduct curves and the expansion path, the isoproduct curve is tangent to the isocost relation that is minimal for that level of output (fig. 1). Expressed as average total unit cost, this cost relationship would be represented by an envelope curve formed as a tangency to a series of short-run cost curves. This long-run average total unit cost curve is an estimate of a long-run production planning curve (fig. 2).

The envelope or long-run average total unit cost curve shown in figure 2 is the simple case of a single homogeneous product and two production inputs. A more complicated problem arises in evaluating unit costs when a firm produces more than one product. When this occurs, the problem of how to measure and combine total output into a single expression increases in difficulty. No completely satisfactory method exists. However, if an assumption of constant relative product prices is made (which differs little from the assumption of constant relative factor prices that is made in constructing the expansion path from the production function), total output can be measured by using total revenue ($TR = P_1q_1 + P_2q_2$).[2] Average total unit cost is then expressed in terms of total cost per dollar of gross revenue.

The data for this study were obtained from a sample of general crop-cotton farms on the eastern side of the San Joaquin Valley. The farms in this survey were classified into size groups according to irrigated acreage. From these data prototype farms with typical characteristics of each acreage size group were developed. Characteristics studied in developing these models were soils, labor, machinery crops, and irrigation systems. Budgets were constructed for each of the farm sizes. All labor was charged at its market value. Interest on investment and operating capital was also included in the budgets. These model farms range from 80 to almost 400 acres, as the hypothesis was that most economies of scale would be found within this range.

To obtain the effect of irrigation water prices

[2] Dean, G. W., and Carter, H. O., Cost-Size Relationships for Cash Crop Farms in Yolo County, Calif. Calif. Agr. Expt. Sta. Mimeo Rept. No. 238, December 1960.

on net income and on economical farm size, the assumption was made that the crops grown on a farm would not be affected by the cost of water; that is, that the product mix or proportion of each crop grown would not change as the price of water was increased.[3] The original budgets included only the fixed costs of the water supply—depreciation, interest, and taxes on the pumping plants and irrigation district assessments. To these fixed costs, a variable cost was added at four different levels. Water was priced at increments of $5 per acre-foot over and above the fixed cost. The purpose of this was to show the effect of current water prices on income and the effect on income of the proposed water prices under the California Water Plan.

Analysis

The cost economies illustrated in figure 3 are based on technical relationships. Long-run average total cost is represented by a curve fitted to each of the calculated short-run average unit costs. Each short-run average cost was derived from budgets for farms of increasing size. The first long-run cost derived was the curve identified as "I" in figure 3. The unit costs include a water cost of $5 per acre-foot. This is about the water cost that is presently paid by farmers in the eastern San Joaquin Valley.

The crops on each budgeted farm are cotton, alfalfa, corn, and barley.[4] The proportional acreage of each of these crops differs for each farm size. As the size of farm increases, the amount of labor, capacity of equipment, and proportion of the poorer soils also change. These changes expand or limit the profitableness of each crop possibility. Acreage allotment regulations were used to establish the cotton acreage. A higher proportion of the intensively cultivated, heavy water-using crops, such as corn and alfalfa, was grown on the smaller farms. Larger farms produced a greater proportion of barley, which requires less extensive cultivation and less water than the other

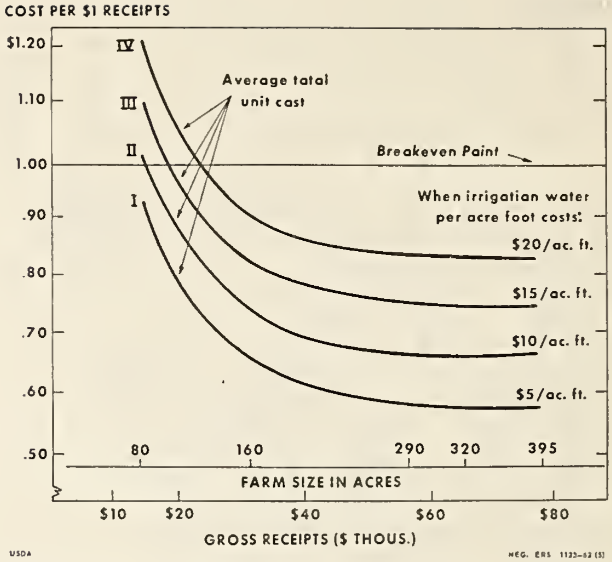

Figure 3.—Average total unit cost of production, San Joaquin Valley cotton farms.

three crops. These variables help to explain why the long-run average cost curves are not parallel throughout their length. The vertical distance between curves is greater at the lower output levels and closer together at the higher output levels.

A small change in the cost of water is immediately reflected in a proportionately large change in net income. Representation of this effect can be noted in figure 3 by comparing the upward shift in the average cost curve with the "breakeven" level of costs and returns.

As figure 3 indicates, most of the economies of scale are realized at an output of about $60,000, or 300 acres of cropland. Thereafter, further decreases in cost are slight. An examination of cost relations beyond the points shown in previous California studies indicates that the slight downward trend in costs would continue as output is increased over a considerable range in farm size.

The smallest farm in this analysis is near the breakeven point of costs and returns, as shown by the relation of the cost curves in the $10,000 to $20,000 range of output. As the cost of water increases, the gross income level for the small farms decreases to a point at which it no longer covers total costs. The breakeven point (total cost[5] =

[3] This assumption seems reasonable within a fairly wide range of water prices because of wide differences in profit margins between crops so that changes in the price of water do not shift relative profits.

[4] These four crops used, respectively, 3.3, 5.0, 4.0, and 1.25 acre-feet of water per acre.

[5] Total cost = fixed cost plus variable costs. The variable costs are at 1960 cost levels for labor and materials.

gross returns) occurs for the smallest farm used in the analysis when the price of irrigation water is raised to about $8 to $10 per acre-foot (curve II).

As farm size increases from about 80 to 320 acres of farmland, costs per dollar of output change from approximately $0.95 to $0.82, a decrease of $0.13. The per unit cost decrease from 320 to about 400 acres of cropland is only about $0.01 to $0.02 per dollar of output. Primarily, the incentive to increase size beyond 320 acres would be associated more closely wth the multiplier effect of a larger number of units than with further possible production cost savings.

Average cost curves II, III, and IV are identical in characteristics with curve I. Their main purpose is to indicate the effect of an increase in the price of water on average total costs in both the short and the long run and to show the effect on net income of a change in the price of water. As the cost of water is increased from $5 to $20 per acre-foot the returns per dollar of cost decreases between $0.25 to $0.30. Small farms cannot continue in business under these circumstances unless, in the short run, the operator is willing to accept a return to family labor that is less than its value in alternative employment.

An acreage restriction on the supply of surface water would also increase the short-run cost in each situation where surface water supplies are required. A water-supply restriction (acreage limitation)[6] would increase the cost per unit of output by forcing a change in the cropping system to less intensive water-using crops. The number of such crops that can be grown successfully in the San Joaquin Valley is limited. An acreage restriction would not affect all farmers in equal degree. As some farmers depend exclusively on well water, surface water restrictions would not affect their costs. For many farmers, however, surface water is used in conjunction with well water to meet peak demand periods. Farmers least affected by a high price for surface water would be those who have adequate well systems, and the most severely affected group would be farmers who depend heavily upon water from surface sources.

[6] Such limitations on farm size as lack of available land will have the same effect.

Summary and Conclusions

The comparisons that have been made of the sample farms[7] provide logical grounds for several generalized statements. These statements are conclusions about the income position of all farms in the sample, the special case of the smaller farms, and the inferences that can be made as to the effect of water policy on income and on the survival characteristics of these farms. Unit production costs are controlled by crop values and crop acreages, by method of operation, and by the amount of purchased inputs used.

Unit costs will increase or decrease depending upon how each of these production particulars varies. Considering the calculated costs only, operators of the smaller farms can pay the present water price and still profit. Their income position is such, however, that a small increase in water prices would eliminate profit. Operators of larger farms could pay a higher price for water and still profit because of unit cost economies. However, considering current cost trends for purchased inputs, taxes and other costs, as well as price instability, the income position of all farmers in the valley becomes more precarious as the cost of water increases.

Projected prices for irrigation water are based on the price estimates that have been made by the California Department of Water Resources. It is estimated that the cost of surface irrigation water under the Feather River Project will be about $20 to $25 per acre-foot in Fresno, Kings, and Kern Counties. This price will not affect all farmers in equal degree. Some farmers depend exclusively upon well water; others require supplemental water from surface distribution sources.

The sample farms used in our analysis are more characteristic of Eastside farms. These farms will not be affected as materially by the Feather River project as will the Westside farms. Surface water sources are now available to these farms. However, water costs and other cost increases on Eastside farms will have the effect shown should they occur as indicated. The most material effect on farm costs for Westside farmers who depend more on surface water than on

[7] Eighty to 400-acre farms, classified as cotton-general crop farms growing cotton, alfalfa, corn, and barley.

wells would come as a result of an acreage limitation on water (imposing current Eastside conditions on the Westside area). A high water price would still absorb considerable profit margin (projecting the slight downward trend in unit costs and comparing the projected cost with anticipated prices for surface water).

Regardless of how farm income is affected, the smaller farmer will be the first to go out of business when substantial cost increases occur.[8] So far, these farmers have managed to survive in considerable numbers, partly because of a certain amount of indirect cost subsidy they have received to pay for surface water and partly because of willingness to take lower returns for their management and labor. A built-in unavoidable higher cost will mean that they cannot continue their farming operations.

[8] The possibility that a farmer will discount his management and labor return, forego imputed interest, and neglect depreciation charges, is expected in the short run.

If acreage limitations are made a condition of water-development plans, that is, a 160- or a 320-acre limitation,[9] and if these restrictions are combined with a high price for water ($20 to $25 an acre-foot), low farm income and an increasing number of business failures will occur. However, if acreage limitations are not mandatory, operators of the larger farms will be able to pay the higher price for water, given present prices for crops produced and present costs for other purchased inputs. Even so, the proportion of the cost paid by the higher value crops must be recognized. Therefore, the more critical prices with respect to income are the price levels for such crops as cotton. Projected higher input costs in total will correspondingly reduce the ability of operators even on the larger farms to pay the high price of water that will be required to repay the capital costs of the proposed California Water Plan for the San Joaquin Valley.

[9] Assuming that the limitation is absolute.

Input-Output Analysis as a Tool in Agricultural Marketing Research

By William H. Waldorf

Economists engaged in agricultural marketing research are frequently called on to obtain information on industrial markets for farm products, costs of advertising and packaging these products, and tax outlays by marketing agencies. Besides these essentially descriptive questions, they may also be asked to appraise such analytical problems as the effect of various farm programs on industries processing and distributing farm products and, of particular current interest, the impact of the European Common Market and of proposed foreign trade programs on American farmers and on agricultural marketing agencies. Anyone familiar with Leontief (*9*) [1] input-output economics will readily see that these descriptive and analytical questions—and a host of similar ones—can be organized and studied within the interindustry framework. A review of the literature indicates that agricultural economists have used input-output analysis extensively in production and regional research (*7, 10*), but its application to agricultural marketing problems has hardly been explored.[2] The main purposes of this paper are (1) to illustrate a few of the more obvious applications of input-output research to problems in agricultural marketing, and (2) to present a recent special aggregation of the Bureau of Labor Statistics Interindustry Study for 1947 (*5*) which can serve as a benchmark for future work in this area.[3] The aggregation highlights farm sectors and agricultural marketing sectors detailed in the Bureau of Labor Statistics approximately 500-sector model. Description of the tables is limited to the essentials needed for an understanding of the suggested applications. The mathematics underlying the analysis appears in a technical appendix (pages 99–101). The author expresses his appreciation to Allen Paul and Frank deLeeuw for their helpful comments.

INPUT-OUTPUT economics comprises (1) the construction of a descriptive transactions table which shows the dollar amount of purchases by each "industry" from each other "industry" in some given period; and (2) input-output *analysis* which attempts to "convert" this descriptive table to a "predictive" tool. These two aspects of input-output research should be distinguished. Controversy rages about the usefulness of this type of research as a predictive tool, *not* about the usefulness of the descriptive transactions table. (See pp. 102–111 for tables referred to in this paper.)

Rejection of input-output analysis should not automatically result in rejection of the descriptive value of the transactions table. In agricultural marketing research, for example, the transactions table can be a very useful supplement to descriptive aggregative series on the total marketing bill for domestic farm food products, the market basket, and the farm share.[4] It can also supplement information on output, productivity, prices, and hourly earnings currently available for the food marketing sector. More broadly, it supplements other descriptive statistics on national income and money flows. Even if we are skeptical about the input-output framework as a predictive tool, we may want it for descriptive purposes.[5]

In effect, the Leontief input-output model simply organizes within an integrated framework much fact-finding that agricultural marketing economists do piecemeal. These organized data can then be used to anticipate "answers" to a broad array of descriptive and analytical questions—at least for a first approximation.

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[1] Italic numbers in parentheses refer to Literature Cited, page 101.

[2] For a notable exception, see Davis and Goldberg (*3*).

[3] The U.S. Department of Commerce and the U.S. Department of Agriculture are currently constructing an input-output matrix for 1958 based on recent census data. This latest effort of the U.S. Department of Agriculture will up-date the earlier estimates for farming sectors for 1955 made by Robert Masucci and others in the Department (*11*).

[4] For definitions of statistics on the marketing bill, the market basket, and the farm share as used by the U.S. Dept. Agr., see Mktg. and Trans. Situation (*15*).

[5] For evaluation of the Leontief input-output model see Nat. Bur. Econ. Res. (*12*); see particularly the chapter by Carl F. Christ, "A Review of Input-Output Analysis," pp. 137–171, and the comment on Christ's paper by Milton Friedman, pp. 171–174.

Interindustry Transactions

Description

Table 1 shows intersector flows of goods and services in *producers'* prices (that is, sellers' prices) by industry of origin and destination. It is divided into two main sections: (1) The processing or intermediate sectors which purchase goods and services in order to carry out their own production for sale to either (a) other intermediate sectors for further processing, or (b) final demand sectors; and (2) the final demand, or autonomous, sectors which make autonomous or independent demands on the intermediate sectors.

Purchases by autonomous sectors (consumption, investment, and others) are recorded in the columns on the right side of the table and, except for competitive imports and inventory depletions, charges against these sectors (wages and salaries, proprietors' income, property income, depreciation, taxes, and so on) are recorded at the bottom of the table.

Competitive imports (imports which are "highly" substitutable for products made in continental United States) and inventory depletions, which are charges against the respective autonomous sectors, are shown on the right side of the table and the entries are prefixed with minus signs. This means that gross domestic output, the last column in the table, measures the value of *current domestic* product.

Reading across a row of table 1 we see, for the sector named at the beginning of the row, its intrasector transactions, its deliveries to other processing sectors, and its deliveries to autonomous sectors in 1947. Thus, in 1947, the meat packing industry sold $110.1 million of its gross output to itself, its sales to poultry-dressing plants were $1.0 million, its sales to canning, preserving and freezing were $37.5 million. Looking at the meat packing sector's sales to the autonomous sector, $7,840.7 million—or three-fourths of its total gross output—went for household consumption; sales for export were $306.6 million, compared with $125.8 million in competitive imports.

Reading down the columns of table 1 we see the purchases—or inputs—of each sector. Returning to the previous illustration, the meat packing sector purchased $7,870.8 million in meat animals from the farm sector, $2.4 million from the poultry and eggs sector, intrasector purchases were $110.1 million, and so on. Looking at the charges against final demand, the meat packing sector had outlays of $137.9 million for Federal taxes, $16.4 million for State and local taxes, and $1,404.9 million for wages and salaries, profits, depreciation, proprietors' income, property income, and other charges.

Total dollar purchases (including profits and taxes) are defined equal to total dollar sales, thus gross domestic outlay (column total) is equal to gross domestic output (row total) for each of the intermediate sectors separately. For the autonomous sectors, column and row totals are *not* equal for each individual sector; the *sum* of the columns for all final demand sectors combined is equal to the combined sum of the rows. This sum is roughly equal to Gross National Product.

The dollar transactions shown in table 1 are all in producers'—not purchasers'—prices; retail charges, wholesale charges, transportation charges, and other distribution costs required to distribute the goods from the producer (seller) to the purchaser are entered as explicit purchases (inputs) by the purchasing sector. This means that purchases of the meat packing sector of $7,870.8 million in meat animals from the farm sector are in farm prices; the charges for transporting and wholesaling the live animals between the farm gate and the meat packing plant are shown in the transactions table as purchases by the meat packing sector from the transportation sector and from the wholesale trade sector. Similarly, sales of "finished" commodities by processors are *not* traced through wholesale and retail trade and therefore are not treated as inputs into the wholesale and retail sectors. Use of this flow process would cause products to lose their identity once they "passed through" a distributive sector.

The treatment of transportation, wholesale, and retail margins in the input-output model should perhaps be amplified. Margins can be looked at from the costs side as the sum of labor costs, capital costs, and so on in distributing goods, or from the expenditures side as the value of output of distributive services. (This is, of course, analogous to the income and expenditures approaches in national income accounting.) Agricultural economists generally focus attention on the cost side.[6] The input-output framework, on the other

[6] For several exceptions to this, see Daly (2) and Fourt (6).

hand, treats transportation, wholesale and retail margins as *output* of these distributive sectors implicitly valued in "base" period prices. That is, the wholesaling and retailing margins shown in table 1 are defined as the value of the 1947 output of these distributive sectors in 1947 dollars. This explicit construction of output of distributive sectors makes the input-output framework especially useful in agricultural marketing research.

The broad aggregation of the distributive sectors in the BLS Interindustry Study hampers somewhat its use in agricultural marketing research. A further breakdown of transportation, wholesale trade, and retail trade by food and nonfood commodities would enable agricultural market research workers to study costs of nonfarm inputs in food distribution as well as in food manufacturing. Though this disaggregation was not done in the BLS Interindustry Study for 1947, it should be at least as feasible with available data as it was in some of the breakdowns actually made.

Applications

For agricultural marketing research perhaps the most obvious application of table 1 is in the study of markets for raw farm products and for processed farm products. Reading across the row of the grain-mill products sector, for example, shows the dependence of this sector's sales—and consequently the sales of farm grains—on *direct* purchases by intermediate sectors; less than a fifth of the gross output of the sector was delivered to households for consumption.

A second application of table 1 is to be found in the detailed breakdown of costs underlying the marketing bill for farm foods that it shows. Thus, in 1947, the meat packing sector purchased $54.9 million from the packaging supplies sector whereas the canning, preserving, and freezing (except fish) sector purchased $359.2 million. A more detailed breakdown of inputs would show outlays for advertising by sector. This detail is actually given in the BLS study, but it is subsumed in the sector labeled "Communications, business and personal services" in our aggregation.

There has been some discussion in the literature on the concept of the Farm-Food Marketing Bill. (*13*) The question is whether a more "net" concept than is now being used might not be better for studying problems of resource allocation. The sum of the rows showing sector payments to Federal, State, and local governments, gross capital formation, and payments to households (rows 101, 102, 103, and 105) is a measure of "value added" in production of the sector named at the top of the column. Thus, this table lends itself to considering various concepts of the marketing bill. We could, for example, estimate the value added (that is, factor requirements in 1947 prices) by each sector in order to deliver a dollar in meat products to households.

Direct Purchases

Table 2 shows the direct purchases of inputs per dollar of output for each intermediate sector; that is, it shows the unit costs structure for each processing sector in 1947. For example, payments by the meat packing sector to the farm sector for meat animals accounted for 76.07 cents of every dollar of sales by the meat packing industry, intrasector purchases accounted for about 1 cent of every dollar of sales, and so on.

Table 2 is derived from table 1 (after some modification) by dividing the transactions in each column by gross current domestic output of the particular sector named at the head of the column. We see that the 76.07 cents figure quoted for the meat packing sector was essentially obtained by dividing that sector's dollar purchases of meat animals ($7,871 million) by the gross output of the meat packing sector ($10,346 million) shown in table 1.

The descriptive uses of table 2 for agricultural marketing research are fairly evident. The table shows the relative importance of costs (in 1947) for different inputs within each marketing sector. Also, it shows the "farm share" of the *wholesale* dollar by agricultural processing sector. (If the distribution sectors were less aggregated the "farm share" of the *retail* dollar could also be readily computed along with a detailed breakdown of costs by distributive sectors in the "market share.")

Input-output analysis—that is, "converting" table 2 from a purely descriptive to an analytical tool—rests on the critical simplifying assumption that the ratios ("coefficients of production") shown in the table are fixed. These ratios are viewed as reflecting physical input requirements per unit of output, expressed in 1947 prices; and changes in these unit requirements are assumed to be small enough so that they can be neglected in short-run analysis. This means, it assumes that for the fore-

casting period considered, unit "physical" input requirements remain essentially unchanged regardless of changes in the level of output or in relative prices of inputs. Given this critical assumption and the quality of data available for constructing the transactions table, even short-term predictions based on the input-output framework should at best be regarded only as first approximations.[7] For long-term projections, the input-output tables can be used as a "base" and supplemented with other information on trends, in "production coefficients," and so on. For some purposes these approximations may be "good enough"; for many others they will probably be the best we can get with limited budget and time; but they are at best first approximations.

Since the purpose of this paper is to illustrate applications of input-output economics in agricultural marketing research, we shall assume the validity of fixed coefficients for expository purposes and describe some "potential" analytical applications of input-output analysis.

Direct and Indirect Requirements

Description

Table 2 shows direct requirements only; one of the more interesting and important uses of input-output economics is to measure indirect requirements. The meaning of indirect requirements can perhaps most easily—and intuitively— be understood by illustration, with the use of table 2.

Table 2 shows that, in 1947, \$1 of gross output in the grain-mill products sector was accompanied by \$0.06342 in intrasector transactions. This means that in order to deliver \$1 of output outside of this processing sector (for example, for household consumption), and to allow for these intrasector transactions, the grain-mill products sector had to have a *gross* output of *at least* \$1.06342. Other entries in this column show that for each \$1 of output, this sector purchased \$0.34183 from the food grain sector, \$0.11959 from the feed grain sector, and so on. Hence, in order for the grain-mill products sector to produce \$1.06342 in gross output, it purchased \$0.36351 (1.06342×0.34183) from the food grain sector, \$0.12717 (1.06342×0.11959) from the feed grain sector and so on.

Turning to the next stage, table 2 shows that in the food grain sector \$1 in gross output is accompanied by \$0.06774 in intra-industry transactions, \$0.07515 in purchases from the feed grain sector, \$0.00690 in purchases from the grain-mill sector and so on. Thus, in order to supply the grain-mill products sector with \$0.36351 in feed grains and so on, so that the grain-mill products sector could in turn deliver \$1 in output outside the processing sectors, the food grain sector had \$0.02462 (0.36351×0.6774) in intrasector transactions, it purchased \$0.02732 (0.36351×0.07515) from the feed grain sector, \$0.00251 (0.36351×0.00690) from the grain-mill products sector, and so on. (This pro-rata allocation is, of course, another critical assumption; particularly critical because of the level of aggregation used in table 2.) Similarly, by looking at the coefficients of the feed grain sector in table 2, we see that intrasector transactions in the feed grain sector were \$0.01209 (0.12717×0.09504), purchases from the grain-mill sector were \$0.00092 (0.12717×0.00720) and so on.

Adding the figures through these stages shows that in order to deliver the \$1 in output to the final demand sector, the grain-mill products sector had a gross output of *at least* \$1.06685 ($1.06342 + 0.00251 + 0.00092$), the food grain sector had a gross output of *at least* \$0.38813 ($0.36351 + 0.024624$), the feed grain sector had a gross output of *at least* \$0.16658 ($0.12717 + 0.02732 + 0.01209$), and so on. This iterative process can, of course, be carried through further stages. Also, the figures as computed are related to deliveries outside the processing sectors and include intrasector transactions; they can be related to total production, including intrasector transactions, or to total production, excluding intrasector transactions (*14*).

Table 3 summarizes the combined direct and indirect requirements from each sector to support shipments from the intermediate sectors to the final demand sectors. It is the *transpose* of the inverse of the matrix obtained by subtracting the coefficient matrix (table 2) from the identity matrix.[8] Reading across a row of table 3, we see the direct and indirect requirements on each sector in order to ship \$1 in gross output to a

[7] For a brief review and bibliography of tests of the validity of the input-output model, see Chenery and Clark (*1*).

[8] For a simplified discussion of the relationship between the iterative process and the simultaneous solution of a system of equations, see Dorfman, Samuelson, and Solow (*4*).

final demand sector. Thus, in order for the meat packing sector to deliver \$1 in gross output to the household sector, \$0.878810 is required in meat animals from the farm sector, \$0.000001 in poultry and eggs from the farm sector and so on. Similarly, in order for the canning, preserving, and freezing (excluding fish) sector to ship \$1 in gross output to households, industries engaged in manufacturing packaging materials had to produce \$0.18 in gross output, both directly and indirectly.

Reading down the columns of table 3 shows the dependence of each sector on the activity of other sectors. Thus, in the column for the meat packing sector we see that for \$1 in gross output shipped outside the intermediate sectors by the meat animals sector, \$0.000003 is required from the meat packing sector; for \$1 in gross output shipped by the poultry and eggs sector, \$0.000173 is required from the meat packing sector; and so on. If we mark out a submatrix, say sectors 11 through 28, we can see the intradependence of these agricultural marketing industries.

Applications

The traditional and probably most important use conceived for input-output analysis is to show the effect of a change in final demand on the gross output of individual sectors. This can be illustrated for the grain-mill products sector with the use of table 3. Column 15 of table 3 shows the total requirements of each sector on the grain-mill products sector in order for the purchasing sector to deliver \$1 for final demand. If we "apply" this column to the bill of goods demanded by the household sector in 1947 (table 1), we find that both direct and indirect requirements on the grain-mill products sector totaled \$3,317.2 million. Comparing this figure with the figure for direct delivery to households (\$993.5 million) shown in table 1 indicates that indirect requirements on the grain-mill products sector were \$2,323.7 million, or 70 percent of the total. The same procedure can, of course, be applied to other sectors individually, or to all sectors simultaneously.

Closely related to applications already noted is the use of input-output analysis to study the effect of a change in final demand on resource requirements. If data on unit-man-hour requirements (man-hours per unit of gross output) by sector are available, we can apply these to the inverse matrix in order to estimate the change in man-hour requirements resulting from a change in final demand. If each of the coefficients in table 3, column 15 were multiplied by man-hour requirements per \$1 of gross output in the grain-mill products sector in 1947; and if to these figures we applied the end-product deliveries to the household sector in 1947, the result would show estimates of the man-hours required in the grain-mill products sector in order to meet each item in the 1947 household bill of goods. For example, the first entry in the grain-mill column would be an estimate of the man-hours in the grain-mill industry needed to meet the 1947 final demand for meat animals after tracing through all the direct and indirect requirements. The inverse can also be used to derive approximate "labor intensities" or "employment multipliers" by sector which could be used in studies of industrial location for rural development.

An analysis similar to that for man-hour requirements can be done for any limited resource (waterpower, fuel, and so on) or for total factor inputs (value added). Each of these analyses would of course require additional simplifying assumptions, and probably adjustments, based on a knowledge of the sectors studied; these empirical questions must be carefully considered by researchers.

All of the applications that have been discussed for a national model apply also to regional input-output models, except that regional models can also be used to study interregional as well as interindustry flows of goods and services. Because of lack of regional data, many agricultural economists engaged in regional input-output studies have had to rely on input coefficients computed from the BLS Interindustry Study for the country as a whole. While this introduces an additional tenuous assumption, it does suggest that work on the national level may be a stimulus to regional efforts. The "ultimate" model, as one might guess, would be a national input-output table that showed interregional as well as interindustry flow (*8*).

Technical Appendix—The Mathematical Model

The economy is treated as comprising $(n+1)$ sectors: n of these are intermediate or processing sectors and the remaining sector is the final de-

mand or autonomous sector. The technical difference between the intermediate and autonomous sectors is that we assume, at least as a first approximation, that while we can establish a simple structural connection among the intermediate sectors, the autonomous "bill of goods" has no such simple restriction on its relations to other sectors.

Let the gross output of the i^{th} sector in any given period be X_i. Some or all of this output will be sold to intermediate sectors (including the i^{th}, itself) for further processing; let the quantity sold by the i^{th} sector to the j^{th} sector be X_{ij}. The other part of the output of the i^{th} sector will be sold to the final demand sector; let this quantity be Y_i. Then our n relations are as follows:

$$
\begin{aligned}
X_1&=X_{11}+X_{12}+X_{13}+\ldots\ldots+X_{1n}+Y_1\\
X_2&=X_{21}+X_{22}+X_{23}+\ldots\ldots+X_{2n}+Y_2\\
&\vdots\\
X_n&=X_{n1}+X_{n2}+X_{n3}+\ldots\ldots+X_{nn}+Y_n
\end{aligned}
\tag{1}
$$

Table 1, the transactions table, consists of these n relations, plus payments to the final demand sector.

In order to "convert" this descriptive table to an analytical tool, we assume that the purchase of any given intermediate sector from another intermediate sector is a function of the output of the purchasing sector and—more critically—that we can approximate this functional relationship by assuming proportionality—i.e., fixed coefficients between the sector's inputs and its output. That is, the purchases of the j^{th} sector from the i^{th} sector, X_{ij}, is proportional to the output of the j^{th} sector. Thus,

$$\frac{X_{ij}}{X_j}=a_{ij}$$

or

$$X_{ij}=a_{ij}X_j \tag{2}$$

From equations (1) and (2) we have,

$$
\begin{aligned}
X_1&=a_{11}X_1+a_{12}X_2+\ldots\ldots+a_{1n}X_n+Y_1\\
X_2&=a_{21}X_1+a_{22}X_2+\ldots\ldots+a_{2n}X_n+Y_2\\
&\vdots\\
X_n&=a_{n1}X_1+a_{n2}X_2+\ldots\ldots+a_{nn}X_n+Y_n
\end{aligned}
\tag{3}
$$

or in matrix notation

$$x=Ax+y \tag{4}$$

where,

$$A=\begin{bmatrix} a_{11} & a_{12} & \ldots\ldots & a_{1n}\\ a_{21} & a_{22} & \ldots\ldots & a_{2n}\\ \vdots & & & \\ a_{n1} & a_{n2} & \ldots\ldots & a_{nn}\end{bmatrix}$$

$$x=\begin{bmatrix} X_1\\ X_2\\ \vdots\\ X_n\end{bmatrix} \qquad y=\begin{bmatrix} Y_1\\ Y_2\\ \vdots\\ Y_n\end{bmatrix}$$

The direct purchases table (table 2), is, of course, the matrix A. To find the output for each sector necessary to meet a bill of final demand, we solve (4) for x. The result is,

$$x=(I-A)^{-1}y \tag{5}$$

where I is the identity matrix and $(I-A)^{-1}$ is the inverse of the identity matrix minus the coefficient matrix. Table 3 is the transpose of this inverse matrix. (The matrix was transposed in order to facilitate computation of inner products with a desk computer.) It shows for each sector both its direct and indirect requirements per unit of gross output.

To study, say, man-hour requirements by sector in order to meet a bill of final demand, we assume a fixed unit man-hour requirement by sector. That is,

$$\frac{M_i}{X_i}=k_{ii}$$

or

$$M_i=k_{ii}X_i \qquad (i=1, 2, \ldots\ldots n) \tag{6}$$

where M_i is the number of man-hours employed

in the production of X_i, and k_{ii} shows unit man-hour requirements in production in X_i. In matrix notation,

$$m=Kx \tag{7}$$

where,

$$K=\begin{bmatrix} k_{11} & 0 & 0 \ldots\ldots 0 \\ 0 & k_{22} & 0 \ldots\ldots 0 \\ 0 & 0 & 0 \ldots\ldots 0 \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \quad\quad 0k_{nn} \end{bmatrix}$$

$$m=\begin{bmatrix} M_1 \\ M_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ M_n \end{bmatrix}$$

Substituting (5) in (7),

$$m=K(I-A)^{-1}y \tag{8}$$

In general, we can follow the same procedure for any limited resource—if we are willing to assume proportionality.

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TABLE 1.—*Interindustry transactions in 1947*—FARM PRODUCTS

(All figures in millions of dollars)

Sector No.	Sector	Meat animals 1	Poultry and eggs 2	Farm dairy products 3	Food grains 4	Oil-bearing crops 5	Fruits and vegetables 6	Other farm food products 7	Cotton 8	Tobacco 9	Feeds, other farm nonfood products 10
	INTERMEDIATE SECTORS										
	Farm products:										
1	Meat animals	1, 196. 5									
2	Poultry and eggs		308. 0								
3	Farm dairy products	130. 0									
4	Food grains	82. 7	183. 0		224. 8						
5	Oil-bearing crops	2. 6				93. 0					
6	Fruits and vegetables	79. 5	. 2				121. 4				
7	Other farm food products							3. 7			
8	Cotton	7. 9		7. 9					27. 4		
9	Tobacco										
10	Feeds and other farm nonfood products	3, 760. 8	1, 100. 5	1, 784. 9	249. 4	56. 4	116. 4	18. 0	141. 0	20. 4	907. 6
	Manufactured farm products:										
11	Meat packing										
12	Poultry dressing plants										
13	Processed dairy products										
14	Canning, preserving, freezing (excluding fish)										
15	Grain-mill products	310. 9	1, 285. 6	540. 5	22. 9	6. 1	15. 7	3. 8	6. 2	. 7	68. 8
16	Bakery products										
17	Vegetable oils	108. 1	14. 9	53. 3							11. 8
18	Sugar	4. 2		12. 9							
19	Other manufactured farm foods		4. 6	9. 0							
20	Tobacco manufactures										
21	Textile mill products								4. 0	8. 2	31. 6
22	Apparel				2. 2	1. 1	33. 9	. 2			6. 9
23	Other manufactured farm nonfoods	6. 6	3. 2	23. 7							1. 8
	Trade, services and other sectors:										
24	Wholesale trade	73. 4	103. 9	50. 2	64. 1	12. 2	62. 4	7. 3	20. 0	5. 9	138. 8
25	Retail trade	135. 2	235. 0	125. 6	50. 6	15. 8	58. 1	7. 5	21. 4	5. 6	189. 2
26	Eating and drinking places										
27	Warehousing and storage	11. 8	3. 1	2. 1	1. 1	. 1	. 8	(*)	. 5	. 1	2. 0
28	Transportation	302. 8	133. 5	123. 6	45. 9	8. 9	75. 8	3. 8	16. 6	6. 8	213. 1
29	Packaging supplies			29. 9			133. 8				1. 6
30	Communication, business, and personal services	274. 6	61. 3	146. 6	512. 9	163. 5	159. 3	39. 9	301. 8	86. 5	1, 239. 7
31	Coal, gas, and electric power	5. 6	16. 5	25. 6	2. 2		3. 8			. 6	7. 1
32	Construction	8. 8	20. 0	97. 8	21. 5	7. 0	4. 2	2. 6	12. 0	35. 8	24. 1
33	All other sectors	76. 5	30. 1	94. 5	162. 3	53. 0	257. 4	26. 3	111. 9	45. 3	660. 9
	FINAL DEMAND SECTORS										
100	Foreign trade (noncompetitive imports)										1. 5
101	Federal Government	30. 7	6. 8	15. 5	45. 4	6. 7	28. 2	4. 0	28. 2	4. 6	88. 7
102	State and local government	90. 3	31. 1	50. 7	66. 2	14. 0	69. 5	8. 3	29. 4	7. 1	189. 3
103	Gross capital formation										
105	Households	2, 868. 5	322. 5	1, 868. 5	1, 847. 3	622. 8	2, 871. 7	185. 0	1, 521. 0	656. 7	5, 766. 2
106	Gross domestic outlays	9, 568. 1	3, 864. 1	5, 063. 0	3, 318. 6	1, 060. 6	4, 012. 4	310. 4	2, 242. 2	884. 2	9, 550. 2

TABLE 1.—*Interindustry transactions in 1947*—Continued—MANUFACTURED FARM PRODUCTS

(All figures in millions of dollars)

Sector No.	Meat packing	Poultry dressing plants	Processed dairy products	Canning, preserving, freezing (excluding fish)	Grain-mill products	Bakery products	Vegetable oils	Sugar	Other manufactured farm foods	Tobacco manufactures	Textile mill products	Apparel	Other manufactured farm nonfoods
	11	12	13	14	15	16	17	18	19	20	21	22	23
INTERMEDIATE SECTORS													
1	7, 870. 8												46. 7
2	2. 4	295. 0	17. 6	26. 7		17. 1			181. 3				
3		9. 8	1, 929. 2			19. 9			5. 8				
4					1, 826. 7				(*)				12. 5
5					25. 1	1. 8	671. 3		92. 0				136. 5
6			20. 0	719. 0	2. 8	13. 2			39. 3				57. 4
7			9. 5			5. 8		180. 4	49. 5	1. 6			. 5
8							290. 9				1, 419. 6	18. 1	
9										796. 9			
10	21. 6			5. 4	639. 1		(*)		303. 4		586. 7		279. 7
11	110. 1	1. 0		37. 5	31. 4	109. 3	0. 7	. 2	71. 7		35. 3		741. 1
12	(*)	61. 0	10. 8	. 3	. 5	(*)	(*)	(*)	37. 0			5. 2	. 1
13	. 2	10. 5	353. 5	2. 4	14. 8	93. 7	(*)	(*)	42. 5				. 4
14	23. 4	. 7	5. 6	34. 1	12. 7	47. 9	. 1	. 2	38. 5				4. 9
15	1. 8	1. 3		20. 3	338. 9	692. 5	29. 5	. 3	91. 0				54. 8
16	. 5	. 4	5. 0	3. 8	5. 4	. 3	(*)	. 1	11. 5				1. 2
17	15. 1			41. 4	246. 4	19. 1	24. 0		711. 3		29. 7		31. 5
18	5. 4	(*)	58. 6	78. 7	30. 6	109. 0	(*)	684. 7	222. 8	4. 3			6. 9
19	13. 7	35. 2	75. 1	149. 1	97. 3	365. 6	178. 4	. 4	495. 6	10. 4	30. 6		46. 8
20										838. 0			
21			. 8						. 9		1, 230. 9	3, 766. 0	91. 0
22	7. 0				184. 1		8. 9	10. 7	2. 3		7. 4	1, 738. 8	6. 0
23	17. 6	. 1	8. 2	. 9	161. 6	. 1	43. 1	(*)	19. 5		35. 0	50. 9	1, 444. 2
24	95. 6	30. 4	61. 5	20. 3	54. 2	53. 4	67. 0	10. 8	75. 3	38. 7	223. 7	364. 6	80. 8
25	. 6	. 1	. 8	. 2	. 5	2. 9		(*)	. 3		(*)		. 5
26													
27	28. 1	. 2	1. 9	1. 9	9. 2	3. 3	3. 5	. 6	5. 1	. 2	22. 6	1. 6	4. 6
28	159. 6	5. 4	61. 8	45. 0	295. 4	92. 7	30. 3	25. 0	146. 4	36. 5	155. 2	89. 3	143. 4
29	54. 9	1. 6	151. 5	359. 2	36. 8	123. 4	5. 6	10. 2	293. 3	115. 8	83. 9	49. 1	328. 6
30	86. 3	5. 1	67. 2	103. 1	122. 3	113. 5	15. 1	18. 2	238. 5	106. 0	163. 9	271. 8	265. 2
31	29. 6	1. 7	27. 5	13. 5	21. 7	25. 2	9. 5	13. 2	23. 6	4. 4	107. 0	35. 7	40. 2
32	18. 4	. 8	12. 5	7. 9	6. 3	10. 1	1. 5	5. 0	11. 0	1. 0	28. 0	11. 2	22. 9
33	224. 3	8. 4	51. 3	87. 4	272. 7	39. 5	78. 2	19. 6	167. 6	72. 4	918. 2	906. 7	603. 8
FINAL DEMAND SECTORS													
100									821. 3	(*)	111. 0	77. 9	3. 8
101	137. 9	7. 9	80. 8	85. 2	135. 0	118. 1	73. 0	24. 5	224. 8	83. 3	537. 7	457. 4	411. 9
102	16. 4	. 9	19. 2	13. 0	13. 4	17. 8	4. 3	6. 2	23. 9	7. 4	56. 3	34. 3	43. 3
103													
105	1, 404. 9	70. 3	616. 7	607. 9	759. 3	1, 266. 7	201. 5	170. 1	1, 201. 1	447. 0	3, 674. 3	4, 682. 7	2, 471. 0
106	10, 346. 4	547. 5	3, 646. 6	2, 464. 2	5, 343. 9	3, 352. 2	1, 737. 0	1, 180. 4	5, 567. 1	2, 564. 0	9, 457. 4	12, 561. 6	7, 382. 1

*Less than $500,000.

TABLE 1.—*Interindustry transactions in 1947*—Continued—TRADE, SERVICES, AND OTHER SECTORS

(All figures in millions of dollars)

Sector No.	Wholesale trade 24	Retail trade 25	Eating and drinking places 26	Housing and storage 27	Transportation 28	Packaging supplies 29	Communication, business and personal services 30	Coal, gas and electric power 31	Construction 32	All other sectors 33
INTERMEDIATE SECTORS										
1										1.0
2			357.6		1.1		0.5			38.5
3			165.5		1.2		.5			42.2
4										12.6
5										2.0
6			261.5		2.1		.8			42.5
7										
8										68.8
9										9.1
10			7.2	8.0	.1	5.9			92.1	342.6
11			704.5		5.3		2.1	0.1		152.5
12	8.5		57.9		2.3	(*)	.9			9.8
13			590.3		4.9	7.8	1.9			128.6
14	1.6		367.4		2.8	.2	1.2	(*)		45.0
15	1.5		95.2		.8	.3	1.0	(*)		62.1
16	(*)		267.3		2.5	(*)	1.0			47.7
17	.7					19.8		(*)	.1	419.1
18			56.3		(*)	.5	(*)	.3	.1	132.0
19	6.3		281.4		2.2	23.2	2.7	1.0	1.4	257.3
20	(*)				.2			.2		29.3
21	13.9	13.3			15.9	52.8	33.6	2.2	47.2	1,390.3
22	8.6	10.3	21.3		3.3	19.5	15.0	.1	1.1	339.4
23	1.1	1.5	986.1		11.6	1.9	35.2	.4	.5	1,021.9
24	69.7	115.1	1,058.2	2.6	200.2	240.6	504.3	39.8	1,315.9	2,318.7
25	70.1	109.7	18.1	1.0	143.9	.1	95.5	1.5	1,199.0	163.3
26					11.5					151.6
27	.6	1.4	9.5	1.6	134.8	3.4	4.3	(*)	7.0	31.2
28	45.4	390.8	342.6	27.8	968.4	368.7	170.1	185.8	1,262.2	3,883.0
29	298.5	462.8	92.0	6.1	10.1	1,874.4	114.5	2.7	271.2	5,087.9
30	2,025.9	4,590.8	881.9	36.5	1,068.7	177.5	5,889.8	147.1	1,481.3	3,787.1
31	88.0	399.0	219.3	16.3	533.4	167.4	526.5	1,271.9	30.3	1,997.4
32	29.3	151.9	75.0	9.2	1,244.3	42.3	4,059.0	263.1		667.2
33	1,085.5	1,207.2	599.4	23.7	1,997.6	3,404.1	6,774.6	1,109.7	10,946.1	52,093.0
FINAL DEMAND SECTORS										
100					357.9		36.0			38.8
101	1,415.3	1,274.7	1,099.7	29.0	1,358.5	525.9	1,607.1	528.5		5,517.2
102	235.8	987.7	315.6	26.4	654.5	57.2	4,239.9	518.9		1,081.7
103										
105	10,819.0	16,523.5	4,590.9	352.9	12,581.7	3,880.8	37,569.1	5,173.7		67,935.6
106	16,225.5	26,239.7	13,521.8	541.2	21,321.8	10,874.2	61,686.4	9,246.6	16,655.5	149,348.0

Table 1.—*Interindustry transactions in 1947*—Continued—FINAL DEMAND SECTORS

(All figures in millions of dollars)

Sector No.	Foreign trade: Exports	Foreign trade: Competitive imports	Federal Government	State and local government	Gross private capital formation	Inventory changes: Additions: Producing sector	Inventory changes: Additions: All other sectors	Inventory changes: Depletions: Producing sector	Inventory changes: Depletions: All other sectors	Households	Gross domestic output
	100		101	102	103	104				105	106
INTERMEDIATE SECTORS											
1	3.7	−15.3		0.3			45.9	−550.3		968.8	9,568.1
2	21.3	−4.9	50.9	4.7			17.8	−28.5	−32.5	2,589.5	3,864.1
3	1.3		19.8	6.5			.1			2,731.2	5,063.0
4	602.1	−3.3				160.9	214.8		−9.3	11.1	3,318.6
5	44.5	−159.4	33.4			131.8	72.9		−94.3	7.4	1,060.6
6	161.3	−145.0	75.1	6.5			4.2	−96.8	−3.3	2,650.7	4,012.4
7	4.5	−42.0					4.1			92.8	310.4
8	394.3	−50.0	22.0			47.6	60.7		−73.0		2,242.2
9	88.2	−.2					192.0	−198.5	−3.3		884.2
10	363.4	−421.7	.3	1.1	21.1		47.0	−1,276.8	−228.4	597.0	9,550.2
11	306.6	−125.8	215.4	19.4		112.6	10.5		−35.2	7,840.7	10,346.4
12	9.0	−6.3	21.1	3.6		16.5	15.3			294.0	547.5
13	253.8	−15.1	110.3	7.1		11.9	8.5		−16.6	2,035.2	3,646.6
14	142.3	−174.2	43.8	4.2		128.3	8.9	−2.2	−28.2	1,755.0	2,464.2
15	766.0	−9.6	39.9	1.3		28.7	1.3	(*)	−129.0	993.5	5,343.9
16	7.8	−.1	.4	5.6		10.4			−31.5	3,012.9	3,352.2
17	63.8	−87.1	8.3			13.6	2.1		−10.0		1,737.0
18	33.3	−798.7	32.8	1.3		40.8		−3.2	−17.1	483.9	1,180.4
19	175.7	−54.4	40.7	5.6		37.2	28.8	−7.7	−62.5	3,316.4	5,567.1
20	220.9	−132.5				47.7	49.8	−.5	−.6	1,484.5	2,564.0
21	955.6	−151.5	231.2	1.8	20.9	39.6	181.9	−5.7	−113.9	1,594.9	9,457.4
22	335.5	−92.1	119.5	37.5	.1	95.4	117.4	(*)	−50.6	9,570.8	12,561.6
23	150.4	−186.6	31.0	8.2	17.4	112.5	158.0		−78.7	3,293.2	7,382.1
24	1,050.7		42.4	26.6	1,258.8		114.9			6,152.5	16,225.5
25				5.4	1,041.5					22,540.7	26,239.7
26										13,358.7	13,521.8
27	25.2		1.9	.4	2.0		3.2			210.3	541.2
28	2,295.9	251.2	542.7	63.8	363.0		106.4			7,837.2	21,321.8
29	333.6	−393.9	86.0	51.5	59.8	78.7	54.3		−98.6	703.4	10,874.2
30	175.7	−55.9	295.0	271.4	1,399.3		.1			34,951.9	61,686.4
31	368.3	−7.1	39.2	164.3		3.3	31.7		−21.7	3,004.9	9,246.6
32											6,911.7
33	7,454.3	−2,817.5	4,390.4	9,024.6	29,263.1	981.4	1,884.6	−198.3	−1,293.8	26,193.8	159,091.8
FINAL DEMAND SECTORS											
100			1,507.0	40.1			2.0			825.2	3,822.5
101	898.8		1,579.2	41.6	240.1		60.7			28,422.9	47,236.1
102	.7			315.8	7.9		4.5			5,120.9	14,379.8
103											
105	914.0		23,406.2	5,698.7	232.3					3,375.0	229,066.1
106	18,621.9	−5,699.0	32,985.9	15,818.9	33,927.3	2,125.9	3,504.4	−2,368.5	−2,432.1	198,020.9	726,189.4

*Less than $500,000.

TABLE 2.—*Direct purchases in 1947*—FARM PRODUCTS

Sector No.	Sector	Meat animals 1	Poultry and eggs 2	Farm dairy products 3	Food grains 4	Oil-bearing crops 5	Fruits and vegetables 6	Other farm food products 7	Cotton 8	Tobacco 9	Feed crops and other farm nonfood products 10
	Farm products:										
1	Meat animals	0. 12505									
2	Poultry and eggs		0. 07971								
3	Farm dairy products	. 01359									
4	Food grains	. 00864	. 04736		0. 06774						
5	Oil-bearing crops	. 00027				0. 08769					
6	Fruits and vegetables	. 00831	. 00005				0. 03026				
7	Other farm food products							0. 01192			
8	Cotton	. 00083		0. 00156					0. 01222		
9	Tobacco										
10	Feeds and other farm nonfood products	. 39306	. 28480	. 35254	. 07515	. 05318	. 02901	. 05799	. 06289	0. 02307	0. 09504
	Manufactured farm products:										
11	Meat packing										
12	Poultry dressing plants										
13	Processed dairy products										
14	Canning, preserving, freezing (excluding fish)										
15	Grain-mill products	. 03249	. 33270	. 10676	. 00690	. 00575	. 00391	. 01224	. 00277	. 00079	. 00720
16	Bakery										
17	Vegetable oils	. 01130	. 00396	. 01053							. 00124
18	Sugar	. 00044		. 00255							
19	Other manufactured farm foods		. 00119	. 00178							
20	Tobacco manufactures										
21	Textile mill products								. 00178	. 00927	. 00331
22	Apparel				. 00066	. 00104	. 00845	. 00064			. 00072
23	Other manufactured farm nonfoods	. 00069	. 00083	. 00468							. 00019
	Trade, Services and Other Sectors:										
24	Wholesale trade	. 00767	. 02689	. 00992	. 01932	. 01150	. 01555	. 02352	. 00892	. 00667	. 01453
25	Retail trade	. 01413	. 06082	. 02481	. 01525	. 01490	. 01448	. 02416	. 00954	. 00633	. 01981
26	Eating and drinking places										
27	Warehousing and storage	. 01023	. 00080	. 00042	. 00033	. 00009	. 00020	(*)	. 00022	. 00011	. 00021
28	Transportation	. 03165	. 03455	. 02441	. 01383	. 00839	. 01889	. 01224	. 00740	. 00769	. 02231
29	Packaging supplies			. 00591			. 03335				00017
30	Communication, business, and personal services	. 02870	. 01586	. 02896	. 15455	. 15416	. 03970	. 12854	. 13460	. 09783	. 12981
31	Coal, gas and electric power	. 00058	. 00427	. 00506	. 00066		. 00095			. 00068	. 00074
32	All other sectors	. 00800	. 00779	. 01866	. 04891	. 04997	. 06415	. 08473	. 04991	. 05123	. 06920

*Less than 0.000005.

TABLE 2.—*Direct Purchases in 1947*—Continued—MANUFACTURED FARM PRODUCTS

Sector No.	Meat packing	Poultry dressing plants	Processed dairy products	Canning, preserving, freezing (excluding fish)	Grain-mill products	Bakery products	Vegetable oils	Sugar	Other manufactured farm foods	Tobacco manufactures	Textile mill products	Apparel	Other manufactured farm nonfoods
	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0. 76073												0. 00633
2	. 00023	0. 53881	0. 00483	0. 01084		0. 00510			0. 03257				
3		. 01790	. 52904			. 00594			. 00104				
4					0. 34183				(*)				. 00169
5					. 00470	. 00054	0. 38647		. 01653				. 01849
6			. 00548		. 00052	. 00394			. 00706				. 00778
7			. 00260	. 29178		. 00173		0. 15283	. 00889	0. 00062			. 00007
8							. 16747				0. 15010	0. 00144	
9										. 31080			
10	. 00209			. 00219	. 11959		(*)		. 05450		. 06204		. 03789
11	. 01064	. 00183		. 01522	. 00588	. 03260	. 00040	. 00017	. 01288		. 00373		. 10039
12	(*)	. 11142	. 00296	. 00012	. 00009	(*)	(*)	(*)	. 00665			. 00041	. 00001
13	. 00002	. 01918	. 09694	. 00097	. 00277	. 02795	(*)	(*)	. 00763				. 00005
14	. 00226	. 00128	. 00154	. 01384	. 00238	. 01429	. 00006	. 00017	. 00692				. 00066
15	. 00017	. 00237		. 00824	. 06342	. 20658	. 01698	. 00025	. 01635				. 00742
16	. 00005	. 00073	. 00137	. 00154	. 00101	. 00262	(*)	. 00008	. 00207				. 00016
17	. 00146			. 01680	. 04611	. 00570	. 02205		. 12777		. 00314		. 00427
18	. 00052	(*)	. 01607	. 03194	. 00573	. 03252	(*)	. 58006	. 04002	. 00168			. 00094
19	. 00132	. 06429	. 02060	. 06051	. 01821	. 10906	. 10271	. 00034	. 08902	. 00406	. 00324		. 00634
20										. 32941			
21			. 00022						. 00016		. 13087	. 29980	. 01233
22	. 00068				. 03445		. 00512	. 00906	. 00041		. 00078	. 13938	. 00081
23	. 00170	. 00018	. 00225	. 00036	. 03024	. 00003	. 02481	(*)	. 00350		. 00370	. 00405	. 19707
24	. 00924	. 05553	. 01686	. 00824	. 01014	. 01593	. 03857	. 00915	. 01353	. 01509	. 02365	. 02902	. 01094
25	. 00006	. 00018	. 00022	. 00008	. 00009	. 00086		(*)	. 00005		(*)		. 00007
26													
27	. 00272	. 00037	. 00052	. 00077	. 00172	. 00098	. 00202	. 00051	. 00092	. 00008	. 00239	. 00013	. 00062
28	. 01543	. 00986	. 01695	. 01826	. 05528	. 02765	. 01744	. 02118	. 02630	. 01424	. 01641	. 00711	. 01942
29	. 00531	. 00292	. 04155	. 14577	. 00689	. 03681	. 00322	. 00864	. 05268	. 04516	. 00887	. 00391	. 04451
30	. 00834	. 00932	. 01843	. 04184	. 02289	. 03385	. 00869	. 01542	. 04284	. 04134	. 01733	. 02164	. 03592
31	. 00286	. 00310	. 00754	. 00548	. 00406	. 00752	. 00547	. 01118	. 00424	. 00172	. 01131	. 00284	. 00545
32	. 02168	. 01534	. 01407	. 03547	. 05103	. 01178	. 04502	. 01660	. 03010	. 02824	. 09486	. 07218	. 08179

*Less than 0.000005.

TABLE 2.—*Direct purchases*—Continued—TRADE SERVICES AND OTHER SECTORS

Sector No.	Wholesale trade 24	Retail trade 25	Eating and drinking places 26	Warehousing and storage 27	Transportation 28	Packaging supplies 29	Communication, business and personal services 30	Coal, gas and electric power 31	All other sectors 32
1									0.00001
2			0.02645		0.00005		0.00001		.00026
3			.01224		.00006		.00001		.00028
4									.00008
5									.00001
6			.01934		.00010		.00001		.00028
7									
8									.00046
9									.00006
10			.00053	0.01478	(*)	0.00054			.00229
11			.05210		.00025		.00003	0.00001	.00102
12	0.00052		.00428		.00011	(*)	.00002		.00007
13			.04366		.00023	.00072	.00003		.00086
14	.00010		.02717		.00013	.00002	.00002	(*)	.00030
15	.00009		.00704		.00004	.00003	(*)	(*)	.00042
16	(*)		.01977		.00012	(*)	.00002		.00032
17	.00004					.00182		(*)	.00281
18			.00416		(*)	.00005	(*)	.00003	.00088
19	.00039		.02081		.00010	.00213	.00004	.00011	.00172
20	(*)				.00001			.00002	.00020
21	.00086	0.00051			.00075	.00486	.00054	.00024	.00931
22	.00053	.00039	.00158		.00016	.00179	.00024	.00001	.00227
23	.00007	.00006	.07293		.00054	.00018	.00057	.00004	.00684
24	.00430	.00439	.07826	.00480	.00939	.02213	.00818	.00430	.01553
25	.00432	.00418	.00134	.00185	.00675	.00001	.00155	.00016	.00109
26					.00054				.00102
27	.00004	.00005	.00070	.00296	.00632	.00031	.00007	(*)	.00021
28	.00280	.01489	.02534	.05137	.04564	.03391	.00276	.02009	.02600
29	.01840	.01764	.00680	.01127	.00047	.17749	.00186	.00029	.03407
30	.12486	.17496	.06522	.06744	.05012	.01632	.09548	.01591	.02536
31	.00542	.01521	.01622	.03012	.02502	.01539	.00854	.13755	.01337
32	.06690	.04601	.04433	.04379	.09369	.28946	.10981	.12001	.34030

*Less than 0.000005.

TABLE 3.—*Direct and indirect purchases in 1947*—FARM PRODUCTS

Sector No.	Sector	Meat animals 1	Poultry and eggs 2	Farm dairy products 3	Food grains 4	Oil-bearing crops 5	Fruits and vegetables 6	Other farm food products 7	Cotton 8	Tobacco 9	Feed crops and other farm non-food products 10
	Farm products:										
1	Meat animals	1. 142925	0. 000001	0. 001553	0. 001640	0. 000581	0. 000098	0. 000001	0. 000237	(*)	0. 497597
2	Poultry and eggs	. 000151	1. 086618	. 000007	. 147071	. 000873	(*)	. 000013	. 000424	(*)	. 394299
3	Farm dairy products	. 000050	. 000002	1. 000002	. 041811	. 000718	(*)	. 000013	. 000327	(*)	. 405016
4	Food grains	. 000001	(*)	(*)	1. 072691	. 000001	(*)	(*)	. 000001	(*)	. 008920
5	Oil-bearing crops	. 000001	(*)	(*)	. 000025	1. 096119	(*)	(*)	. 000002	(*)	. 006542
6	Fruits and vegetables	(*)	(*)	(*)	. 000016	(*)	1. 031204	(*)	. 000006	(*)	. 003312
7	Other farm food products	. 000001	(*)	(*)	. 000485	. 000003	(*)	1. 012064	. 000002	(*)	. 006666
8	Cotton	. 000001	(*)	(*)	. 000011	. 000001	(*)	(*)	1. 012375	(*)	. 007041
9	Tobacco	(*)	(*)	(*)	(*)	(*)	(*)	(*)	. 000017	1. 000000	. 002551
10	Feeds and other farm non-food products	. 000001	(*)	(*)	. 000031	. 000007	(*)	(*)	. 000010	(*)	1. 105034
	Manufactured farm products:										
11	Meat packing	. 878810	. 000001	. 001194	. 001261	. 000454	. 000075	. 000008	. 000186	(*)	. 382632
12	Poultry dressing plants	. 000119	. 658924	. 003283	. 098337	. 000993	. 000001	. 000026	. 000437	(*)	. 240502
13	Processed dairy products	. 000035	. 000090	. 585832	. 024509	. 000566	. 000063	. 000701	. 000248	(*)	. 237329
14	Canning, preserving, freezing (excluding fish)	. 001367	. 001220	. 000003	. 000352	. 001146	. 000001	. 300648	. 000457	(*)	. 003112
15	Grain-mill products	. 000416	. 000010	. 000018	. 391521	. 002354	. 000001	. 000035	. 001141	(*)	. 144615
16	Bakery	. 003103	. 000496	. 001716	. 081325	. 007483	. 000050	. 001851	. 002948	(*)	. 032977
17	Vegetable oils	. 000417	. 000419	. 000007	. 000835	. 439869	. 000009	. 000186	. 175964	(*)	. 005151
18	Sugar	. 000001	(*)	(*)	. 000177	. 000001	(*)	. 368323	. 000014	(*)	. 002427
19	Other manufactured farm foods	. 001298	. 003992	. 000063	. 001359	. 063692	. 000081	. 001766	. 024684	(*)	. 009608
20	Tobacco manufactures	(*)	(*)	(*)	(*)	. 000004	(*)	. 000011	. 000010	. 463472	. 001183
21	Textile mill products	. 000043	(*)	(*)	. 000002	. 000019	(*)	(*)	. 174846	(*)	. 009124
22	Apparel	. 000020	(*)	(*)	. 000001	. 000007	(*)	(*)	. 060926	(*)	. 003181
23	Other manufactured farm nonfoods	. 109968	(*)	. 000149	. 000217	. 002610	. 000109	. 000002	. 000304	(*)	. 053139
	Trade, Services and Other Sectors:										
24	Wholesale trade	. 000001	. 000001	(*)	(*)	(*)	(*)	(*)	. 000001	(*)	. 000001
25	Retail trade	. 000001	(*)	(*)	(*)	. 000001	(*)	(*)	. 000001	(*)	. 000001
26	Eating and drinking places	. 005394	. 002915	. 003794	. 000751	. 000178	. 001996	. 000843	. 000066	(*)	. 005077
27	Warehousing and storage	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	. 001638
28	Transportation	(*)	(*)	(*)	(*)	(*)	(*)	(*)	. 000001	(*)	. 000001
29	Packaging supplies	. 000009	(*)	. 000001	(*)	. 000019	(*)	(*)	. 000029	(*)	. 000021
30	Communication, business, and personal services	. 000003	(*)	(*)	(*)	. 000003	(*)	(*)	. 000005	(*)	. 000006
31	Coal, gas and electric power	. 000004	(*)	(*)	(*)	. 000003	(*)	(*)	. 000005	(*)	. 000007
32	All other sectors	. 000025	. 000001	. 000001	. 000001	. 000021	(*)	. 000001	. 000036	(*)	. 000053

*Less than 0.0000005.

TABLE 3.—*Direct and indirect purchases in 1947*—Continued—MANUFACTURED FARM PRODUCTS

Sector No.	Meat packing	Poultry dressing plants	Processed dairy products	Canning, preserving, freezing (excluding fish)	Grain-mill products	Bakery products	Vegetable oils	Sugar	Other manufactured farm foods	Tobacco manufactures	Textile mill products	Apparel	Other manufactured farm nonfoods
	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.000003	(*)	(*)	(*)	0.004183	(*)	0.001370	0.000003	0.000163	(*)	0.000027	0.000018	0.000023
2	.000173	(*)	0.000012	0.000009	.386047	0.000004	.002002	.000063	.001013	(*)	.000553	.001547	.001463
3	.000058	(*)	.000004	.000003	.114029	.000001	.001677	.000081	.000437	(*)	.000176	.000458	.000495
4	.000001	(*)	(*)	(*)	.000080	(*)	.000002	(*)	.000001	(*)	.000006	.000003	.000004
5	.000001	(*)	(*)	(*)	.000068	(*)	.000002	(*)	.000001	(*)	.000010	.000014	.000004
6	(*)	(*)	(*)	(*)	.000043	(*)	.000001	(*)	.000001	(*)	.000037	.000102	.000001
7	.000001	(*)	(*)	(*)	.001323	(*)	.000008	(*)	.000004	(*)	.000007	.000007	.000008
8	.000001	(*)	(*)	(*)	.000031	(*)	.000001	(*)	.000001	(*)	.000025	.000001	.000003
9	(*)	(*)	(*)	(*)	.000001	(*)	(*)	(*)	(*)	(*)	.000108	(*)	.000001
10	.000001	(*)	(*)	(*)	.000085	(*)	.000016	(*)	.000003	(*)	.000047	.000003	.000004
11	1.010759	(*)	(*)	.000023	.003217	(*)	.001071	(*)	.000142	(*)	.000022	.000015	.000039
12	.000137	1.125392	.002398	.000021	.234517	.000004	.002274	.000124	.008682	(*)	.000337	.000940	.000893
13	.000041	.000038	1.107349	.000019	.066842	.000016	.001316	.004309	.002800	(*)	.000104	.000269	.000322
14	.001572	.000001	.000002	1.014035	.000941	.000015	.002675	.007780	.007047	(*)	.000025	.000011	.000020
15	.000478	(*)	.000033	.000026	1.067779	.000011	.005397	.000172	.002745	(*)	.001489	.004276	.004041
16	.003568	.000009	.003120	.001467	.221788	1.002632	.017108	.008985	.122422	(*)	.000311	.000890	.000884
17	.000479	.000009	.000010	.000008	.002271	.000002	1.037848	.001116	.117020	(*)	.000038	.000077	.003213
18	.000001	(*)	(*)	(*)	.000482	(*)	.000003	2.381293	.000002	(*)	.000090	.000255	.000004
19	.001493	.000084	.000094	.000078	.003652	.000024	.145584	.010619	1.114145	(*)	.000012	.000026	.000416
20	(*)	(*)	(*)	(*)	.000001	(*)	.000010	.000060	.000069	1.491224	.000052	.000001	.000001
21	.000049	(*)	(*)	(*)	.000006	(*)	.000044	(*)	.000046	(*)	1.150583	.000002	.000055
22	.000023	(*)	(*)	(*)	.000002	(*)	.000016	(*)	.000016	(*)	.400811	1.161954	.000079
23	.126375	(*)	(*)	.000004	.000502	(*)	.000202	.000004	.000113	(*)	.001773	.000004	1.245446
24	.000001	.000001	(*)	(*)	(*)	(*)	.000001	(*)	.000001	(*)	.000006	.000002	.000003
25	.000001	(*)	(*)	(*)	(*)	(*)	.000001	(*)	.000001	(*)	.000006	.000001	.000004
26	.006203	.000049	.004841	.002758	.002007	.001982	.000365	.000179	.002597	(*)	.000024	.000027	.009089
27	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	.000001	(*)	.000001
28	(*)	(*)	(*)	(*)	(*)	(*)	.000001	(*)	(*)	(*)	.000003	(*)	.000002
29	.000010	(*)	.000002	(*)	.000001	(*)	.000044	.000002	.000043	(*)	.000140	.000040	.000046
30	.000004	(*)	(*)	(*)	(*)	(*)	.000906	(*)	.000004	(*)	.000023	.000005	.000017
31	.000004	(*)	(*)	(*)	(*)	(*)	.000007	.000001	.000005	(*)	.000025	.000006	.000018
32	.000029	(*)	.000002	.000001	.000001	.000001	.000048	.000004	.000034	(*)	.000177	.000040	.000130

*Less than 0.0000005.

TABLE 3.—*Direct and indirect purchases in 1947*—Continued—TRADE, SERVICES AND OTHER SECTORS

Sector No.	Wholesale trade 24	Retail trade 25	Eating and drinking places 26	Warehousing and storage 27	Transportation 28	Packaging supplies 29	Communication, business and personal services 30	Coal, gas and electric power 31	All other sectors 32
1	0. 000864	0. 002621	(*)	0. 000015	0. 005044	0. 000087	0. 076175	0. 000057	0. 018252
2	. 004251	. 007650	(*)	. 000008	. 007395	. 000173	. 087001	. 000154	. 023200
3	. 000936	. 003364	(*)	. 000003	. 004295	. 000182	. 069799	. 000122	. 020119
4	. 002171	. 001664	(*)	(*)	. 001691	. 000174	. 185306	. 000088	. 039042
5	. 001354	. 001656	(*)	(*)	. 000229	. 000176	. 188366	. 000084	. 039847
6	. 001646	. 001507	(*)	(*)	. 002102	. 004242	. 005580	. 000038	. 012918
7	. 002474	. 002472	(*)	(*)	. 001433	. 000170	. 145800	. 000082	. 037504
8	. 000166	. 000114	(*)	(*)	. 000191	. 000141	. 151801	. 000067	. 033081
9	. 000087	. 000069	(*)	(*)	. 000114	. 000041	. 011238	. 000018	. 009689
10	. 001686	. 002201	(*)	(*)	. 002697	. 000171	. 159376	. 000088	. 038284
11	. 000764	. 002015	(*)	. 000039	. 005523	. 000151	. 058705	. 000088	. 017449
12	. 008882	. 004652	(*)	. 000005	. 004653	. 000238	. 054147	. 000141	. 017133
13	. 002453	. 001974	(*)	. 000002	. 004537	. 005747	. 043610	. 000199	. 017184
14	. 001382	. 000749	0. 000001	. 000001	. 003300	. 180167	. 049193	. 000563	. 096854
15	. 002159	. 000894	(*)	. 000019	. 007205	. 000261	. 091565	. 000130	. 028386
16	. 002329	. 000220	(*)	. 000006	. 004864	. 005630	. 025987	. 000164	. 012233
17	. 004778	. 000692	(*)	. 000021	. 002401	. 000949	. 103632	. 000141	. 030185
18	. 001133	. 000900	(*)	. 000002	. 005835	. 000342	. 057213	. 003145	. 021104
19	. 002231	. 000150	(*)	. 000004	. 003503	. 007223	. 022132	. 000125	. 013897
20	. 002337	. 000032	(*)	(*)	. 002339	. 008259	. 012403	. 000078	. 015756
21	. 002802	. 000036	(*)	. 000028	. 002083	. 000229	. 030011	. 001555	. 023402
22	. 004384	. 000013	(*)	. 000010	. 000849	. 000198	. 013747	. 000602	. 021514
23	. 001526	. 000267	(*)	. 000006	. 003321	. 006845	. 013821	. 000143	. 021878
24	1. 004389	. 000046	(*)	(*)	. 000136	. 002393	. 138757	. 000135	. 034359
25	. 000129	1. 004201	(*)	(*)	. 001696	. 002327	. 194391	. 001862	. 040746
26	. 007930	. 000066	1. 000000	. 000001	. 002812	. 000737	. 009509	. 001909	. 009389
27	. 000070	. 000022	(*)	1. 002969	. 005441	. 001413	. 007792	. 003536	. 009313
28	. 000125	. 000071	. 000001	. 000066	1. 047875	. 000069	. 005890	. 003067	. 016453
29	. 003545	. 000007	. 000005	. 000001	. 005795	1. 218019	. 004239	. 003022	. 535814
30	. 000381	. 000019	. 000002	(*)	. 000539	. 000791	1. 106140	. 000399	. 184554
31	. 000383	. 000003	. 000002	(*)	. 003022	. 000879	. 002708	1. 159827	. 211875
32	. 002387	. 000017	. 000016	. 000001	. 004169	. 006302	. 004651	. 002380	1. 519903

*Less than 0.0000005.

Book Reviews

Managing Farm Surpluses.

By Frederick V. Waugh. Planning Pamphlet No. 117. National Planning Association, Washington. 90 pages. April 1962. $1.75.

THIS PAMPHLET is the result of work done by Mr. Waugh while on leave from the U.S. Department of Agriculture under a Senior Research Award in Governmental Affairs from the Social Science Research Council. Although it presumably is written for a nonprofessional audience, it has the characteristics that have distinguished his professional writings—subtle blend of theory and common sense, the adept use of illustration and anecdote, and clarity of presentation which leaves the reader convinced. In fact, the reader may be too convinced on some issues.

The pamplet begins with the sensible assertion that we shall continue to have farm surpluses, and that, therefore, the problem before us is how to best make use of them. It starts with a discussion of the magnitude of the problem, examines the various alternative uses of the surpluses, and ends with a program for managing agricultural surpluses.

In his introductory section, Waugh defines surplus "as the amount that cannot be sold in normal competitive channels of trade at an established or agreed upon price, and with no subsidy at all." But, as he moves on, it is clear that he is implicitly defining a surplus as that quantity of farm products which will reduce factor returns to resources in agriculture to unsatisfactory levels. His programs are those which would move on all fronts to improve factor returns in agriculture, assuming they are likely to be low indefinitely into the future.

Waugh's prescription for managing the surpluses are: First priority, defense reserves; second priority, domestic food distribution via a food stamp plan; third priority, export assistance. He is willing to go along with further research on industrial uses, promotional campaigns, and self-help programs although he is not optimistic as to their probable impacts. The only thing which he definitely opposes is the destruction of surplus agricultural products.

Waugh correctly recognizes that a program of adequate defense reserves will have little impact upon the continuing problem of surplus disposal. Even so, I think the author's high priority is well placed; for we appear unconscious of the probable effect that a minor, much less a catastrophic, interruption of our food supply would have upon our economy. It is reckless to ignore adequate food reserves, given our huge stocks of farm surplus products and other unemployed resources in the economy.

The author clearly believes that an expanded food stamp program deserves more attention than it has received in the postwar period, and his arguments for it are persuasive. While I agree with him to a large extent, there are some points in his analysis I should like to question.

First, he classifies food stamp plans as diversion programs, having previously classified diversion programs as those where one maximizes net returns from markets with different price elasticities. He then goes on to suggest that a food stamp plan, *even if financed by farmers*, would increase their net revenue. This appears questionable to me.

An initial evaluation of the pilot food stamp plans started in 1961 showed that increased *food expenditures* represented about 90 percent of the value of the subsidy. Actually, this must vastly overstate the increase in demand for farm produced products. Much of the increased expenditures apparently went for *increased* marketing services. For instance, Detroit participants increased their dairy product consumption less than 1 percent in volume, but 43 percent in value; their bakery products consumption by 29 percent in volume and 47 percent in value, while reducing their volume of flour and other cereals; and their

consumption of potatoes and sweet potatoes 5 percent in volume and 27 percent in value.

Now I would not want to argue that a shift from dried milk to French vanilla ice cream or from boiled potatoes to potato chips is undesirable; and, in fact most of the big shifts were to animal products, fruits, and vegetables. I should think, however, that the price elasticity of these low-income groups for the farm component of food would have to be much higher than that of nonparticipants in order for a nonsubsidized program to increase income. I am not familiar with evidence of this substantially higher elasticity. Therefore, while I would favor expanded food stamp programs as good multipurpose welfare programs, I believe they are a very expensive way to increase the incomes of farmers.

In general, Waugh's discusssion of our export diversion programs is balanced and good. I do wish, however, he had devoted more attention to cutting through the confusion that is involved in our foreign currency sales. The continued illusion that these represent a certain (usually high) value to the recipients and a given budget cost (quite low) to us seems likely to prove dangerous over time to both our foreign aid and farm program. There would appear to be little question as to the desirability of using our surpluses to the best advantage abroad. The use of completely fictitious book-keeping may hinder rather than help achieve this objective by malallocating them both in quantity and destination.

The author has made excellent use of the economic principles that underlie diversion and subsidy programs, and enable these programs to be used to improve farm income. At the same time he tends to brush aside such principles as efficient resource use, comparative advantage, and marginal utility. I wonder if they are not as important in program analysis as the others used?

In summary, I would recommend this pamphlet to all interested in farm policy. It explains clearly why we are doing some of the things we are doing, why we will continue doing them despite frequent objections from many sources, and why we should do more of some of them. This is a significant feat in 90 pages. I should not be surprised if opponents of the programs feel there are some missing points; but, given the assumptions with which the author began, I think the most relevant issues were discussed.

Dale E. Hathaway

Dynamics of Land Use—Needed Adjustment

By Iowa State University Center. Iowa State University Press, Ames, Iowa. 371 pages. 1961. $4.95.

THE PROBLEMS of land use adjustment are central to most farm program proposals. This collection of papers from the Adjustment Center Land Use Conference of 1960 covers the following areas: Need for adjustment; regional aspects of production adjustment; the impact of farm adjustment on the community at large; and farm programs.

In the introductory chapter, Earl Heady observes that in dealing with adjustment problems we cannot separate land, capital, and labor. And we lack adequate tools to deal with the land variable. We do not have the data that we need in order to fit land into an aggregate production function.

The demands for new uses of land are developed in chapters by Marion Clawson and Burnell Held. Clawson stresses the importance of intermediate recreational facilities. Cities, themselves, are not users of vast quantities of land but there is need for large acreages within commuting distance of urban populations. Clawson places this need at 25 million acres.

Several chapters are devoted to examination of the production potential for crops. Shrader and Riecken hold that shifts in rotations will have greater influence on output than will yields per acre. With existing technology, corn production in the Corn Belt could have been increased from 2.1 billion bushels in 1955 to 4.6 billion bushels in 1960.

Louis Nelson surveys the physical potential of crop production. The unutilized potential for fertilizer application is noteworthy. We use a fourth of the fertilizer rate applied in France or the United Kingdom and from a tenth to a fifteenth of the rate used in northern Europe. Nelson also points out that we could double the efficiency of use of irrigation water.

Frederick Hopkins analyzes the production potential for forest products. He observes that the opportunity cost of capital is crucial to timber production, and timber production is stimulated by transferring resources to firms with low alternative rates of returns. Therefore, the best opportunities to produce timber are possessed by the large integrated timber companies and the

Government. This view is at variance with proposals to encourage production on small holdings. Forestry also can be encouraged by actions to increase the marginal efficiency of capital in forestry through public assistance in management, disease control, reduction of risk, and more favorable taxation. Hopkins notes that "by subsidizing forest production to a relatively small extent, society has the opportunity to desubsidize agriculture substantially."

Carroll Bottum notes that all of the seriously considered adjustment programs would take land out of production. This result would transpire even with free market prices. Negotiable quotas and low prices would require the least retirement, perhaps 40 million acres. Retirement of marginal land would require the most diversion—perhaps 80 million acres. Income support programs will continue to be needed to supplement land retirement.

John Schnittker contrasts the effects of land development and land adjustment programs. He considers research and extension to have the greatest effects on increasing output. Development programs are a contradiction in a period of surplus but they can be rationalized and it is only realistic to assume that they will be continued.

Numerous specific land adjustment programs are analyzed. Philip Raup and Elmer Learn contrast alternative means of controlling supplies and the consequences for land withdrawal. They regard transferable allotments as involving a new legal concept that shifts the right to produce from real property to personal property. Chryst and Timmons emphasize the importance of land institutions to agricultural problems and their solution. They outline a program that would "divert the program-created income stream now flowing through land titles toward a longrun adjustment in the earning opportunities of farm people." Their scheme would involve production rights that would be temporary and would be acquired by individuals on the basis of bids. Howard Ottoson explores the impact of land retirement on communities and suggests means of lessening the effects.

Dynamics of Land Use will be a useful reference for formulators of policy, for farm leaders, and program administrators. It deals competently and in depth with the whole scope of the land adjustment problem.

Orlin J. Scoville

The Southern Appalachian Region: A Survey.

Edited by Thomas R. Ford. University of Kentucky Press, Lexington, Kentucky. 308 pages. 1962. $10.

IN GENERAL, the economic and social problems of the Southern Appalachian region are well known. Public policies and programs in the past have not been sufficient to enable this important region to share fully in the economic growth of the Nation, so as to relieve the chronic poverty that prevails among a large proportion of its people.

The study of the problem of too great a population pressure on too few resources was the concern of the relatively limited regional survey of economic and social conditions of this underdeveloped area almost 30 years ago. At that time the investigation was mainly concerned with the causes for the area's problems. Since then, many fragmentary economic and social studies of the Appalachian area have been conducted to develop a better understanding of localized problems. In total, these studies have been insufficient to develop comprehensive policies and programs for the economic development of the region.

The urgent need for a comprehensive study of the region's resources, the important changes that have occurred during the last three decades, and potentials for economic and social development were recognized to be basic to the development of programs designed to increase this region's living standards to the national level. This concern for the region was the basis of a conference which resulted in the planning of a series of studies which would analyze all aspects of economic and social activity in the Southern Appalachian region. The Southern Appalachian studies were financed largely by the Ford Foundation, assisted by area colleges and universities and public agencies; they were administered by Berea College.

Extensive regional surveys were conducted to measure social and economic changes in order to gain some insight into the relationships between those changes and the values, beliefs, and attitudes of the people affected by them. Most of the people in the region now have the major goals and standards typical of American society. An important guideline for policy determination is that the old stereotypes that have so long guided social action in the region no longer apply to the great majority of the residents.

This report consists of 19 chapters developed by an interdisciplinary group of research specialists who have done an excellent job in presenting the region with respect to its human, physical, and economic resources, cultures, obstacles, and potentials for economic development. The subjects of each chapter were well selected and developed so as to present the reader with a comprehensive understanding of the progress made by the people in the region, as well as the region's many problems. The human resource of the region and the investments needed to properly develop this important national resource received adequate recognition. The chapter on agriculture could have been more helpful, if the authors had incorporated the 1959 agricultural census data in their analyses. Important changes in the structure of agriculture occurred during the period 1954–1959.

The Southern Appalachian Studies group made a timely and important contribution by providing those interested in furthering the development of this important region with an objective analytical perspective of all aspects governing economic and social activity. In addition, early recognition is given to the overriding influences of our national and international policies and programs. Future development of the Southern Appalachian is a challenge to our Nation. It is the hope of those concerned that this comprehensive regional study will be translated into sound, progressive, and practical program activities for the purpose of ameliorating the intolerable conditions of poverty that prevail throughout the region.

E. L. Baum

Mathematics for Economists: An Elementary Survey.

By Taro Yamane. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 554 pages. 1962. $9.75.

THIS BOOK is, as the title indicates, an elementary survey of mathematics for economists. It is one of the most complete treatments of mathematics commonly used in economics that has yet appeared. Students with a course in algebra will find little difficulty in understanding the material presented.

The main topics covered in the book are sets, functions and limits, differentiation, integration, maxima and minima of functions (both unconstrained and constrained), series, differential equations, difference equations, vectors and matrices, probability and distributions, statistical concepts and hypotheses testing, game theory, and regression and correlation analysis. The chapter on set theory is brief and set notation is not used in the rest of the book, with the exception of the chapter on probability. The treatment of the other sections of the book are thorough and done with great clarity. The sections on maxima and minima and on vectors and matrices are particularly good. Also, the mathematical treatment of regression and correlation analyses, together with the coverage of matrix algebra and statistical concepts, provide students with a basis for an introduction to econometrics.

The topics are treated in a heuristic manner and proofs and derivations are not provided. However, this is not a serious shortcoming since the book is a survey of mathematics.

Economic problems and concepts are presented throughout the book and exercises and references are given at the end of each chapter. It is unfortunate that the author did not include more economic problems at the end of the chapters. This would have given students a better appreciation of the roll of mathematics in economics.

This book provides an excellent text for a full year course in mathematics for economists. Some of the subject matter will have to be supplemented with other references; in particular, the sections on set and game theory. However, the need for supplemental material is minimal.

Martin E. Abel

Vertical Integration in Theory.

By O. P. Blaich. Institute of Agriculture, University of Minnesota, St. Paul. 82 pages. 1961.

SINCE vertical integration problems caught the interest of the profession 6 or 7 years ago, enough has been written to conclude that (1) changing vertical interfirm market relationships raise some problems, (2) alleviate others, and (3) the historical novelty of such changes has been exaggerated. A review of the material also shows that the conceptual apparatus which has been used to approach the subject is piecemeal and particularistic. Blaich's report deserves attention as an attempt to overcome this difficulty.

Blaich sets the task of explaining limits to horizontal and vertical growth of a firm under the restraint of a "fixed" supply of managerial talents. These talents are required to achieve coordination of the diverse activities of the enterprise. Alternative extremes for achieving coordination are the market price mechanism and managerial direction; various intermediate techniques such as forward contracting are assumed available to the enterprise.

The firm is defined conventionally, complete with a profit maximizing entrepreneur who has perfect knowledge of his alternatives and their profit consequences. Under the assumptions of eventual constant costs for each minimal activity, that is, an economically feasible stage in a chain of production, perfect interactivity markets, and fixed supply of management, a long run equilibrium is discovered. At some compounding of vertical stages under a single management, the ability to coordinate and supervise breaks down so that the average costs of an integrated firm became greater than those of non-integrated firms. The limit to vertical growth, under perfectly competitive exchange conditions, are set thereby.

This analysis is extended to situations in which interactivity competition is imperfect. Since marginal gains from integration of either complete or intermediate forms are greater under imperfect competition, firms will tend to extend their vertical control more than when faced with a "perfect" market mechanism.

Blaich eschews application to real industry problems, although he examined integration possibilities in hog production within the lines of his approach in an earlier paper (*Journal of Farm Economics*, December 1960). The paucity of refutable hypotheses means that we have here a "model," not a "theory."

This is more than a quibble. It leads Blaich to assert more generality for his approach than is shown by his evidence. If we take his as a first effort toward developing models of firm growth under varying sets of restraints, it can find a place to stand. It is particularly difficult to believe that a model which assumes away the vexing influence of uncertainty has very great explanatory or predictive power.

There is still a question whether the marginal approach is likely to produce the best conceptualizations of vertical and horizontal firm growth problems. Organizational analysis, after all, attempts to deal directly with the problem of specialization and coordination within the firm. More help for the tool users may be forthcoming from this workshop than from our old suppliers.

Arthur L. Domike

Selected Recent Research Publications in Agricultural Economics Issued by the United States Department of Agriculture and Cooperatively by the State Universities and Colleges[1]

ANDERSON, D. E., LOFTSGARD, L. D., ERICKSON, L. E. CHARACTERISTICS AND CHANGES OF LAND OWNERSHIP IN NORTH DAKOTA 1945 TO 1958. N. Dak. Agr. Expt. Sta. Bul. 438, 28 pp., illus. Jan. 1962. (Econ. Res. Serv. cooperating.)

In 1958, nearly three-fourths of North Dakota's farm and ranch land was owned by active farmers, the State and Federal governments owned 6.7 percent, and non-operator landlords owned approximately one-fifth. The active farmers had mortgages on 31 percent of the farmland they owned and this mortgage debt was 6.3 percent of the total value of land. In 1945 to 1958 the average size of ownership units increased from 488 acres in 1945 to 622 acres in 1958. The concentration of land—referring to distribution of acreage and value among persons who are owners—changed very little from 1945 to 1958.

BIRD, RONALD, AND MILLER, FRANK. CONTRIBUTIONS OF TOURIST TRADE TO INCOMES OF PEOPLE IN MISSOURI OZARKS. Mo. Agr. Expt. Sta. Res. Bul. 799, 69 pp., illus. Mar. 1962. (Econ. Res. Serv. cooperating.)

This is an evaluation of opportunities for enlarging the economic base in the Missouri Ozarks, an area of low farm incomes, by using resources for recreation. Of the total volume of business of retail and service firms in the Missouri Ozarks in 1959, more than 21 percent was obtained from tourists. Though population has decreased since 1950, the number of retail and personal service firms has increased 32 percent mainly due to the tourist trade.

BROWN, W. HERBERT. PEANUT-COTTON FARMS: ORGANIZATION, COSTS, AND RETURNS; SOUTHERN COASTAL PLAINS, 1944–60. U.S. Dept. Agr., Agr. Econ. Rpt. 7, 31 pp., illus. Apr. 1962.

Net farm income on peanut-cotton farms in the Southern Coastal Plains rose from $1,500 per farm in 1946 to $3,500 in 1958, but remained low in comparison with income on other major types of farms. A major factor in the income boost was increased output. From 1944 to 1960, estimated normal yields of peanuts, cotton and corn increased 51, 75, and 129 percent, respectively.

BUCK, R. C., AND BIBLE, B. L. EDUCATIONAL ATTAINMENT AMONG PENNSYLVANIA RURAL YOUTH. Pa. Agr. Expt. Sta. Bul. 686, 25 pp. Nov. 1961. (Agr. Mktg. Serv. cooperating.)

Sample selected in 1947 consisted of members of sophomore classes from 74 rural high schools. Students were studied until 1957. Fifteen percent of the males and 20 percent of the females not finishing high school had intelligence quotient scores of 105 and over. Fifteen percent of the sample of more than 2,000 young people did not finish high school. Thirty-nine percent terminated their formal educations with high school graduation. Thirty-one percent engaged in some post high school training of less than college level. Fifteen percent attended or graduated from colleges or universities.

FRYE, R. E. EFFECT OF THE PILOT FOOD STAMP PROGRAM ON RETAIL FOOD STORE SALES. U.S. Dept. Agr., Agr. Econ. Rpt. 8, 13 pp., illus. Apr. 1962.

Retail food sales increased 8 percent in sample stores used to test the Food Stamp Program. Launched last spring on a trial basis in eight pilot areas, the program has two main purposes: To improve diets of needy families and utilize more of the Nation's abundant food resources.

GAARDER, R. O., ENGLEMAN, GERALD, AND KIMBRELL, E. F. GRADES OF HOGS SLAUGHTERED IN THE UNITED STATES, SEPTEMBER 1960 THROUGH AUGUST 1961. U.S. Dept. Agr., Econ. Res. Serv. and Agr. Mktg. Serv., ERS–57, 16 pp. Apr. 1962.

Based on carcasses graded by a USDA hog grading specialist at a sample of 56 packing plants, about 33 percent of all barrows and gilts and 34 percent of sow carcasses were estimated to have been U.S. No. 1. Estimates of the proportion of hogs coming to market in each U.S. grade will help provide a benchmark by which to measure progress in hog quality improvement.

GRAY, L. R., AND WILLIS, R. J. PRICES AND PRICE SPREADS FOR EGGS, FRYING CHICKENS, AND TURKEYS IN SELECTED CITIES, 1956–61. U.S. Dept. Agr., Econ. Res. Serv., ERS–60, 18 pp., illus. Apr. 1962.

Price spreads for eggs and poultry differed considerably among 10 cities due to directness of marketing channels, retail store pricing policies, and sources of supply. Farm-to-retail price spreads among the cities ranged from 15.4 to 30.1 cents a dozen for grade A large eggs, 15.5 to 37.8 cents a pound for frying chickens, and 15.1 to 27.8 cents a pound for medium turkeys.

HARTMAN, L. M., AND TOLLEY, G. S. EFFECTS OF FEDERAL ACREAGE CONTROLS ON COST AND TECHNIQUES OF PRODUCING FLUE-CURED TOBACCO. N.C. Agr. Expt. Sta. Tech. Bul. 146, 34 pp., illus. June 1961. (Econ. Res. Serv. cooperating.)

This study attempts to find the most profitable production practices under input prices expected *with* and *without* acreage controls. Practices of major concern are levels of nitrogen and number of plants per acre. The

[1] State publications may be obtained from the issuing agencies of the respective States.

study indicated that in the absence of a program, a reduction in number of plants per acre would be profitable. Present levels of nitrogen are found to be most profitable with or without the program.

Henderson, P. L., Hind, J. F., and Brown, S. E. promotional programs for lamb and their effects on sales. U.S. Dept. Agr., Mktg. Res. Rpt. 522, 22 pp., illus. Jan. 1962.

Two techniques for promoting sales of lamb are described: (1) Advertising and education programs sponsored by the American Sheep Producers Council to create greater consumer awareness of lamb and to obtain support of the trade; (2) cooperative advertising arrangements between the Council and retailers in which the Council reimbursed retailers for a portion of the cost of advertising lamb in newspapers. Taking into account both the lower cost and the greater increase in sales, the cooperative advertising was about six times as effective as the regular promotion when measured in terms of the average increase obtained for a dollar's worth of promotional expense.

Jackson, Donald. economics of sugarbeet marketing. U.S. Dept. Agr., Econ. Res. Serv., ERS-49, 36 pp., illus. Mar. 1962.

Possible changes in contracts between growers and processors of sugarbeets are examined. The net returns to all processors from sugar sale might be averaged to arrive at growers' payments. Also, the grower-processor relationship might be modified by contracts providing fixed prices for sugarbeets; division of processed products instead of income; beet production by the processors; custom processing for the growers; or operation of the factories by growers.

Johnson, Ralph D. the conservation reserve program in nebraska. Nebr. Agr. Expt. Sta., SB-470; 31 pp., illus. Feb. 1961. (Econ. Res. Serv. cooperating.)

About 5 percent of the total Nebraska cropland acreage reported by the 1954 Census of Agriculture was in the conservation reserve in 1960. Present plans of owners for future use of land now in conservation reserve suggest that the long-run effects of the program in Nebraska will be more beef and dairy cattle, fewer crop acres, and a more stable agriculture.

Loftsgard, L. D., Anderson, D. O., and Nordbo, M. T. owning and operating costs for farm machinery. N. Dak. Agr. Expt. Sta. Bul. 436, 24 pp., illus. Sept. 1961.

This report provides information on maximum acreage that can be handled efficiently by typical machinery combinations; the fixed costs, variable costs, and total costs of owning and operating farm machinery; and a guide to aid individual farm operators in determining whether a machine should be purchased or if its services should be custom hired.

Manchester, A. C. the organization of the wholesale fruit and vegetable market in washington, d.c. U.S. Dept. Agr., Mktg. Res. Rpt. 524, 27 pp., illus. Feb. 1962.

The Washington wholesale produce market received 23,700 carlots of fresh fruits and vegetables in 1958. Total volume received increased about 50 percent between 1936 and 1958, largely due to the increase in population in the area. During this same period, direct receipts of wholesale handlers increased about 10 percent while those of chains and the one retailer cooperative more than doubled.

Mears, Leon G. agriculture and food situation in cuba. U.S. Dept. Agr., Econ. Res. Serv., ERS-Foreign-28, 22 pp., illus. May 1962.

Food supplies now inadequate. Food consumption has dropped over 15 percent in the last 2 years. Prevailing food shortages and rationing are the product of agricultural output at less than 1957–58 levels, reduced food imports, and gross mismanagement in food marketing and distribution.

Micheel, C. C., and Nauheim, C. W. economics of soil conservation, northeastern kansas. Kans. Agr. Expt. Sta., Agr. Econ. Rpt. 101, 69 pp., illus. Dec. 1961. (Econ. Res. Serv. cooperating.)

Analyzes costs and benefits of conservation practices and systems of farming of major soils in the Walnut Creek Watershed in Northeastern Kansas. The unproductive area now ranges from 2 to 7 percent of all cropland, depending upon soil situation and system of farming. Conservation practices considered in the report are terraces, waterways, rotations, grade stabilization structures, retired cropland, contour farming, and use of fertilizer and lime.

Simmons, Will M. an economic study of the u.s. potato industry. U.S. Dept. Agr., Agr. Econ. Rpt. 6, 83 pp., illus. Mar. 1962.

Serious instability in price and income results from year-to-year variations in production, and from the inelastic demand for potatoes. Between 1920–24 and 1960–61, yield per acre almost tripled, while acreage declined almost 60 percent. Meanwhile, total production increased less than a fourth, from 223 million to 274 million cwt. Processing took a fourth of all 1960 crop potatoes used for food, compared with a negligible quantity in 1940.

U.S. Economic Research Service. proceedings of national workshop on promotion of farm products: michigan state university, east lansing, michigan, october 26–27, 1961. U.S. Dept. Agr., Econ. Res. Serv., ERS–58, 82 pp., illus. Apr. 1962.

Specific objectives of the workshop were: To focus on some of the basic issues surrounding the development, execution, and evaluation of promotional programs sponsored by agricultural commodity organization; and to summarize information from recent research which could be used as guidelines by commodity groups in improving promotional efforts.

Youmans, E. Grant. leisure-time activities of older persons in selected rural and urban areas of kentucky. Ky. Agr. Expt. Sta. Prog. Rpt. 115, 42 pp. Mar. 1962. (Econ Res. Serv. cooperating.)

Leisure-time activities of 1,236 men and women aged 60 and over were examined. Interviews were held in 1959 with older persons, almost half of whom lived in the same household with one or more of their children. Listening to the radio or watching television programs held first place for a hobby or pasttime, reading was second, visiting was third, and gardening and sewing tied for fourth place. Church activity was the most common (and usually only) community activity for the older people.

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(Continued from inside front cover.)

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